(54) **Adaptive modulation method and apparatus**

Adaptives Modulationsverfahren und -System

Procédé et dispositif de modulation adaptatif

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Description

Background of the Invention

5   Field of the Invention

[0001]   The present invention relates to an adaptive modulation method which can be applied to a mobile communications system, and more particularly to an adaptive modulation method for changing a modulation level based on a channel power gain.

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Description of the Related Art

[0002]   In digital communications, particularly in mobile communications systems, it is widely known that channel quality (such as a bit error rate) significantly degrades by variations in the received signal-to-noise ratio (SNR) due to fading.

15 This phenomenon occurs when signal waves are affected by delayed signal waves including scattered signal waves. That is, the amplitude and the phase of a signal varies with time. The fading varies occur in the range of several tens of dBs.

[0003]   The modulation method which is not adaptive to a fading channel (hereinafter referred to as a non-adaptive modulation method) is a method with which a modulation level (and a transmission power) is fixed. If this modulation method is applied, a fairly large link margin must be secured in order to maintain the channel quality allowed by the

20 system in a time period during which the signal level drops due to fading (deep fades). To secure the link margin, for example, a strong error correction which trades off a transmission bandwidth must be applied. Namely, the system to which the non-adaptive modulation method is applied is effectively designed for the worst case channel conditions. Accordingly, with such a system, the channel capacity over fading channels cannot be efficiently utilized.

[0004]   In recent years, an adaptive modulation method intended to efficiently utilize the capacity over a fading channel

25 has been actively studied and developed.

[0005]   The bit error rate performance of a modulation method depends on the distance between signal points implemented with the modulation method, that is, on Eb/No (or Es/No). This is common to any modulation methods.

[0006]   Also an error correction technique intended to improve channel quality is a technique for regularly extending the distance between signal points by using redundant bits.

30 [0007]   In fading channels, the probability of occurrence of the worst conditions is considerably small. That is, communications are made under the condition better than the maximum bit error rate allowed by the system in most of the total time. Accordingly, an optimum transmission can be realized by performing control so that the required bit error rate is maintained with an adaptive change of a transmission power level, a transmission symbol rate, a modulation level, a coding rate, or their combination, depending on a channel condition. This is the principle of an adaptive modulation method.

35 [0008]   Adaptive modulation techniques provide high average spectral effectively by transmitting at high data rates with higher modulation levels under favorable channel conditions, and reducing throughput via lower modulation levels or transmission-off as the channel degrades.

[0009]   The measurement of the channel condition can be performed by the instantaneous received SNR and the average received SNR.

40 [0010]   Fig. 1A shows the principle of the adaptive modulation method. In this figure, x(i) is a transmission signal output from a transmitter 1501 at a station A which is a first station, y(i) is a received signal received by a receiver 1503 at a station B which is a second station opposing the station A, g(i) is a time-varying gain due to fading, and n(i) is an additive white Gaussian noise (AWGN).

[0011]   For a bidirectional communications system, two sets of the system shown in Fig. 1A, which has reverse trans-

45 mission directions, are included.

[0012]   If the channel 1502 is a channel on which the fading of the link in the first direction (from the station A to the station B) correlates with that of the link in the second direction (from the station B to the station A), for example, a TDD (Time Division Duplex) channel, the following control operations are performed.

[0013]   A channel estimator 1506 within the receiver 1503 at the station B on the first direction link estimates the power

50 gain of the channel 1502, and notifies of the estimated channel information a demodulator/decoder 1507 within the receiver 1503 at the station B. The demodulator/decoder 1507 demodulates/decodes the received signal y(i) received from the first direction link after equalization based on the estimated channel information. Furthermore, the channel estimator 1506 within the receiver 1503 at the station B notifies an adaptive modulator/encoder 1504 within the transmitter 1501 at the station B on the second direction link, of the estimated channel information (or the estimated information

55 obtained by applying an extrapolation-interpolation to the estimated power gain). The adaptive modulator/encoder 1504 sets the modulation level information according to the notified estimated channel information, and sends the transmission signal x(i) along with the modulation level information to the second direction link on the channel 1502.

[0014]   The channel estimator 1506 within the receiver 1503 at the station A on the second direction link estimates the

power gain of the channel 1502, and notifies of the estimated channel information the demodulator/decoder 1507 within the receiver 1503 at the station A. The demodulator/decoder 1507 demodulates/decodes the received signal y(i) received from the second direction link after equalization based on the estimated channel information. Additionally, the channel estimator 1506 within the receiver 1503 at the station A notifies the adaptive modulator/encoder 1504 within the transmitter 1501 at the station A on the first direction link, of the estimated channel information (or the estimated information obtained by applying an extrapolation-interpolation to the estimated power gain). The adaptive modulator/encoder 1504 sets the modulation level information according to the notified estimated channel information, and sends the transmission signal x(i) along with the modulation level information to the first direction link on the channel 1502.

[0015]   In this way, a reciprocating transmission of the modulation level information can be implemented.

[0016]   In the meantime, if the channel 1502 is a channel on which the fading of the first direction link does not correlate with that of the second direction link, for example, an FDD (Frequency Division Duplex) channel, the following control operations are performed.

[0017]   First of all, the channel estimator 1506 within the receiver 1503 at the station B on the first direction link estimates the power gain of the channel 1502, and notifies of the estimated channel information the demodulator/decoder 1507 within the receiver 1503 at the station B. The demodulator/decoder 1507 demodulates/decodes the received signal y(i) received from the first direction link after equalization based on the estimated channel information. Additionally, the channel estimator 1506 within the receiver 1503 at the station B feeds back its estimated channel information (or the estimated information obtained by applying an extrapolation-interpolation to the estimated power gain) to the adaptive modulator/encoder 1504 within the transmitter 1501 (shown in Fig. 1A) at the station A on the first direction link by using a feedback channel 1508 for the first direction link. The adaptive modulator/encoder 1504 sets the fed-back modulation level information, and sends the transmission signal x(i) along with the modulation level information to the first direction link on the channel 1502.

[0018]   Also the second direction link requires exactly the same feedback mechanism as that described above.

[0019]   In Fig. 1A, a power controlling unit 1505 within the transmitter 1501 implements the above described power adaptation process.

[0020]   Fig. 1B exemplifies the signal point arrangements implemented with respective modulation methods which can be selected by the adaptive modulator/encoder 1504 within the transmitter 1501 and the demodulator/decoder 1507 within the receiver 1503. As the modulation methods, QPSK (Quadri-Phase Shift Keying), 16QAM (16 Quadrature Amplitude Modulation), 64QAM, etc. can be selected.

[0021]   Since the adaptive modulation method requires the processing unit for adaptively controlling a modulation method as described above, it has the trade-off between the performance and the complexity unlike the non-adaptive modulation method.

[0022]   With the above described conventional adaptive modulation method, the modulation level information set by the adaptive modulator/encoder 1504 within the transmitter 1501 must be added as a control signal on the transmission signal x(i) sent by the transmitter 1501, as stated before. Therefore, the transmission efficiency degrades.

[0023]   This control signal must be sent every state change period (such as every normalized maximum fading frequency). Because an error of the control signal causes the entire received information for one period (one block) to be lost, the error rate of the control signal must be decreased to a fairly low level. Accordingly, the conventional adaptive modulation method requires also the redundancy for correcting an error of the control signal.

[0024]   Up to now, also the method for preventing the transmission efficiency from decreasing by embedding the modulation level information in the control signal (such as a preamble) used for another purpose, and (not by estimating but) by demodulating the control signal on a receiving side has been proposed. This method, however, imposes a restriction on the pattern of the control signal, which leads to a lack of generality and universality.

[0025]   Soliman S. Samir et al.: "Signal Classification Using Statistical Moments", IEEE Transaction on Communications, 1992, discloses a modulation classification system for sorting the modulation type of a signal. The even-order moments of the phase of the signal are used for determining the M-ary PSK modulation.

Summary of the Invention

[0026]   The present invention was developed in the above described background, and aims at preventing the transmission efficiency of a signal from decreasing by allowing the maximum likelihood estimation of a modulation level to be made on a receiving side without transmitting any control signal from a transmitting side, particularly in an adaptive modulation method for changing a modulation level based on a channel power gain.

[0027]   The present invention assumes a radio transmission technology for adaptively changing a modulation level according to the state of a transmission path.

[0028]   The present invention is defined in the independent claims. Particular embodiments are defined in the dependent claims.

[0029]   A first aspect of the present invention has the following configuration.

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[0030] First of all, the mean or the expectation value of a carrier wave power is calculated for received signals to which no modulation level information is added when being sent.

[0031] Next, the difference between the calculated mean or expectation of the carrier wave power of received signals, and a mean or an expectation of the carrier wave power, which is prescribed for each modulation level, is calculated as the likelihood of each modulation level.

[0032] Then, the modulation level corresponding to the maximum likelihood value among the likelihood values of respective modulation levels is estimated as the modulation level of the received signals.

[0033] With the configuration according to the first aspect of the present invention, the differences between average CNRs of respective modulation levels when a bit error rate (that is, an instantaneous Es/No) is made constant, are considered and the likelihood values based on these differences are used, so that the maximum likelihood estimation of a transmitted modulation level can be made only from received signals without obtaining the conventionally required modulation level information when the signals are transmitted, in a radio transmission technology for adaptively changing the state of a transmission path within a system expected to be operated under a fading environment such as a mobile communications environment, etc.

[0034] Namely, with the above described configuration according to the present invention, the absolute value of a likelihood value, that is, the dynamic range of the likelihood value can be reduced by performing a likelihood calculation for each received symbol, thereby saving computer resources in an actual apparatus.

[0035] A second aspect of the present invention has the following configuration.

[0036] First of all, the variance of a carrier wave power is calculated for received signals to which no modulation level information is added when being sent.

[0037] Then, the difference between the calculated variance of the carrier wave power of received signals and a variance of the carrier wave power, which is prescribed for each modulation level, is calculated to be a likelihood of each modulation level.

[0038] Then, the modulation level corresponding to the maximum likelihood value among the likelihood values of respective modulation levels is estimated as the modulation level of the received signals.

[0039] With the above described configuration according to the second aspect of the present invention, the maximum likelihood estimation of a modulation level can be made with a higher accuracy only from received signals by considering the differences between the variances of signal points at respective modulation levels, and by using the likelihood values based on these differences.

[0040] A third aspect of the present invention has the following configuration.

[0041] First of all, the sample variance of the carrier wave power is calculated for signals to which no modulation level information is added when being sent.

[0042] Next, the difference between the calculated sample variance of the carrier wave power of received signals and a sample variance of the carrier wave power, which is prescribed for each modulation level, is calculated to be the likelihood of each modulation level.

[0043] Then, the modulation level corresponding to the maximum likelihood value among the likelihood values of respective modulation levels is estimated as the modulation level of the received signals.

[0044] With the above described configuration according to the third aspect of the present invention, the maximum likelihood estimation of a modulation level can be made with a higher accuracy only from received signals by using a likelihood value based on the distance between the sample variance of a signal point of received signals, and the sample variance at each modulation level.

[0045] A fourth aspect of the present invention has the following configuration.

[0046] The variance of a carrier wave power is calculated for the received signals to which no modulation level information is added when being transmitted.

[0047] Next, the difference between the calculated variance of the carrier wave power of received signals and a sample variance of the carrier wave power, which is prescribed for each modulation level, is calculated to be the likelihood of each modulation level.

[0048] Then, the modulation level corresponding to the maximum likelihood value among the likelihood values of respective modulation levels is estimated as the modulation level of the received signals.

[0049] With the above described configuration according to the fourth aspect of the present invention, the maximum likelihood estimation of a modulation level can be made with a higher accuracy and a higher operation efficiency only from received signals by using the likelihood value based on the distance between the variance of a signal point of received signals and the sample variance at each modulation level.

[0050] In the configurations of the present invention described so far, an estimation block length of a signal sent at a same modulation level can be set according to an estimation error rate allowed by a system. This also means that if a block length is set based on a fading cycle, the estimated number of symbols (block length) can be set to an arbitrary value which is equal to or smaller than the estimated number.

[0051] As a result, since a period (such as a normalized maximum fading frequency) for which a modulation level is

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desired to be changed becomes longer particularly in a moderate or high-speed system, the estimation of a modulation level can be made with a higher accuracy by estimating the modulation level on the entire period. Additionally, an estimation block length can be shortened without changing an allowed estimation error rate in this case, which leads to the reduction in the complexity.

[0052]   In the configurations of the present invention described so far, a received signal level is obtained, so that the modulation level range in which a likelihood value is calculated can be restricted based on the obtained received signal level.

[0053]   Consequently, the amount of the entire estimation calculation process can be reduced.

[0054]   In the configurations of the present invention described so far, the modulation level range in which a likelihood value is calculated can be restricted when a current estimation is made, based on the modulation level which is most recently estimated.

[0055]   As a result, the amount of the entire estimation calculation process can be reduced.

[0056]   In the configurations of the present invention described so far, a subsequent estimation operation of a likelihood value at a corresponding modulation level can be suspended if the information about the distance between signal points, which is calculated by a different maximum likelihood value determination algorithm, exceeds a certain threshold value.

[0057]   Consequently, the amount of the entire estimation process can be reduced.

[0058]   In the configurations of the present invention described so far, a non-adaptive modulation method can be implemented by fixedly setting a modulation level at the time of a transmission.

[0059]   In consequence, the real coexistence of an adaptive and a non-adaptive modulation method can be realized in a system where, for example, the adaptive modulation method is employed only in one direction although both of the methods coexist, or the maximum commonality can be provided to both a base station and a terminal in a system where the adaptive modulation method is employed in both directions.

Brief Description of the Drawings

[0060]   One skilled in the art can easily understand additional features and objects of this invention from the description of the preferred embodiments and some of the attached drawings. In the drawings:

Figs. 1A and 1B explain the principle of an adaptive modulation method;

Fig. 2 is a block diagram showing the principle of the present invention;

Fig. 3 is a block diagram showing the configuration of a first preferred embodiment according to the present invention;

Fig. 4 shows the comparison between a conventional transmission format and a transmission format according to the first preferred embodiment of the present invention;

Fig. 5 explains the operations of the first preferred embodiment according to the present invention;

Fig. 6 shows the configuration of each estimating unit according to the first preferred embodiment of the present invention;

Fig. 7 shows the configuration of each estimating unit (a branch metric value calculating unit for estimating a modulation level) according to a second preferred embodiment of the present invention;

Fig. 8 shows the configuration utilizing an RSSI signal, according to a third preferred embodiment of the present invention;

Fig. 9 shows the configuration employing an adaptive modulation method which performs up/down control of a modulation level, according to a fourth preferred embodiment of the present invention;

Fig. 10 shows the configuration of a fifth preferred embodiment according to the present invention, which is a method combined with a Viterbi decoding method;

Fig. 11 exemplifies the case where a calculation operation is suspended as a result of a threshold determination according to the fifth preferred embodiment of the present invention;

Fig. 12 shows the configuration of the system where adaptive and non-adaptive modulation methods coexist;

Fig. 13 shows the configuration of respective estimating units according to a sixth preferred embodiment of the present invention;

Fig. 14 shows the configuration of respective estimating units according to a seventh preferred embodiment of the present invention; and

Fig. 15 shows the configuration of respective estimating units according to an eighth preferred embodiment of the present invention.

Description of the Preferred Embodiments

[0061]   Provided hereinafter are the explanations about the details of the preferred embodiments according to the present invention, by referring to the drawings.

<First Principle of the Present Invention>

[0062] Fig. 2 shows the principle of the present invention.

[0063] The present invention considers the differences between average CNRs of respective modulation levels.

[0064] Assume that a Square-QAM modulation method is adopted. If its modulation levels are 2(QPSK), 4(16QAM), and 6(64QAM) in this case, their average CNRs are respectively $\gamma_{QPSK}=\delta/\sigma_N{}^2$, $\gamma_{16QM}=5\delta/\sigma_N{}^2$, and $\gamma_{64QAM}=21\delta/\sigma_N{}^2$. Here, 2δ is the (minimum) distance between signal points, while σ^2 is a variance of thermal noise. The theoretical values of the respective average bit error rates are calculated based on these average CNRs.

[0065] As is known from these values, the average CNRs of the respective modulation levels differ on the condition that the symbol error rates are made equal by making the distances between signal points and the thermal noise, that is, Es/No identical. The present invention utilizes this fact.

[0066] Specifically, according to the first principle of the present invention, the power of a received signal is measured by using as standard offset values the average carrier wave powers (P_{ML}s) such as $P_{QPSK}=2.0$, $P_{16QAM}=10.0$, and $P_{64QAM}=42.0$ at the respective modulation levels when no thermal noise exists ($\sigma_N{}^2 \rightarrow 1$) and the distance between signal points is 2. Here, the state change period (hereinafter referred to as a block length) preset by a system is defined to be "L", the number of symbols used for making an estimation (estimation block length) is defined to be "N" (L≥N), and the received signal point at a time point "i" is defined to be r(i). In this case, the likelihood function Λ_{ML} of each modulation level (ML) is represented by the following equation.

$$\Lambda_{ML} = \left| N \cdot P_{ML} - \sum_{i}^{N} r_{(i)}^2 \right| \qquad (1)$$

[0067] Accordingly, the likelihood functions Λ_{QPSK}, Λ_{16QAM}, and Λ_{64QAM} are respectively represented by the following equations.

$$\Lambda_{QPSK} = \left| N \cdot P_{QSPK} - \sum_{i}^{N} r^2(i) \right|, \qquad (2)$$

$$\Lambda_{16QAM} = \left| N \cdot P_{16QAM} - \sum_{i}^{N} r^2(i) \right|, \qquad (3)$$

$$\Lambda_{64QAM} = \left| N \cdot P_{64QAM} - \sum_{i}^{N} r^2(i) \right|, \qquad (4)$$

[0068] According to the first principle of the present invention, the function having the minimum value (the maximum likelihood value) among likelihood functions Λ_{ML} corresponding to respective modulation levels is used as an estimation result of a modulation level.

[0069] Namely, modulation level estimating units 102 #1 through #X calculate likelihood functions $\Lambda_{ML\#1}$, $\Lambda_{ML\#2}$, ..., $\Lambda_{ML\#X}$ from received signals 101 based on the equation (1) (the specific examples of which are the equations 2 through 4).

[0070] Additionally, modulation level demodulating units 103 #1 through #X perform demodulation processes corresponding to the respective modulation levels ML#1, ML#2, ... ML#X for the respective levels.

[0071] Then, a maximum likelihood function value selector 104 selects the function having the minimum value from among the likelihood functions $\Lambda_{ML\#1}$, $\Lambda_{ML\#2}$, ..., $\Lambda_{ML\#X}$ output from the modulation level estimating units 102 #1 through #X, and makes a data selector 105 output as a demodulation signal 106 the output of the modulation level demodulating unit 103, which corresponds to the minimum value.

[0072] Note that, however, the variances of signal points at respective modulation levels when identical measurement symbols are used are different from one another even if the variance of thermal noise is the same. This is because the number of sample symbols must be set to a larger value with the increase of a modulation level in order to make the

frequency of occurrence of all the signal points at a certain modulation level same when a random information source is assumed. For example, there is the following relationship between the variances of average carrier wave powers at respective modulation levels when the number of samples is "N", which are represented by the equations 2 through 4.

$$\sigma^2_{P_{QPSK}} < \sigma^2_{P_{16QAM}} < \sigma^2_{P_{64QAM}} \qquad (5)$$

[0073]   This means that the present invention is based on Law of Large Numbers, and a variance $\sigma^2 P_{ML}$ of an average carrier wave power (mean) at each modulation level approaches "0" and a sample average value $\bar{r}^2$ over the "N" samples approaches the mean, as "N" is set to a larger number.

[0074]   As described above, according to the first principle of the present invention, each likelihood function value is calculated on the condition that the number of samples "N" is set to a same value. Therefore, two parameters such as the variance σ^2 of thermal noise (which is common to respective modulation levels), and the variance $\sigma^2 P_{ML}$ of the carrier wave power (mean) of each modulation level must be considered.

[0075]   The former variance depends on Es/No, while the latter variance depends on a modulation level (particularly on the modulation level having a maximum transmission efficiency). Especially, for the latter variance, if a sufficient number of samples cannot be measured (if "N" is small), a transmission error (an irreducible error) can occur even if there is no thermal noise. As a matter of course, if the number of measurement samples is small although the former variance (used for a conventional Viterbi decoding algorithm as a model assumption) is large, an estimation accuracy degrades.

[0076]   Accordingly, an estimation error of a modulation level, which is caused by the above described interaction, can be prevented from occurring if the number of samples "N" is set to some large value.

[0077]   When a system is designed, the number of samples "N", which satisfies the allowed value of an estimation error rate, is determined not only from the normalized maximum fading frequency viewpoint, but also from the block error rate (or the modulation level estimation error rate) viewpoint.

[0078]   By way of example, with the 64QAM modulation method having the maximum transmission efficiency among the above described combination of the modulation levels, the estimation error rate is increased to as high as approximately 4×10^{-4} when the number of symbols "N" is 30.

[0079]   The above described number of symbols N=30 is the number equivalent to that of per pilot period (several tens of symbols), for example, if the transmission speed is lower than that of a pilot signal period "L" used for fading compensation. If the transmission speed is medium or high, the number of symbols becomes considerably smaller than that of per pilot period (several hundreds to several thousands of symbols).

[0080]   That is, if a modulation level is changed with a pilot signal period, an estimation with a fairly high accuracy (errorless estimation) can be implemented particularly at a moderate or high-speed.

[0081]   Described above is the fundamentals of the first principle of the present invention.

[0082]   In a demodulation process of a modulation method with a high modulation level, particularly, the demodulation process of the QAM modulation method, a signal point is determined based on a threshold of the distance between signal points. In this case, the coordinate of a received signal in a signal space, and that of the signal point closest thereto are used as input information. Therefore, the units performing the calculations, which are additionally arranged when the present invention is applied, are only three units: a unit for calculating a power value (square value) of a received signal, a unit for making an accumulation in one block, and a unit for adding (to be more exact, subtracting) an offset value of an average carrier wave power of an estimated modulation level. Note that, however, the number of sets of this configuration, which corresponds to the number of estimated modulation levels, must be prepared.

[0083]   This is the specific example of the configuration according to the first principle of the present invention.

[0084]   Here, the equation (1) can be transformed into the following equation having the form of the sum of calculation equations for respective symbols.

$$\Lambda_{ML} = \left| \sum_{i}^{N} (P_{ML} - r^2(i)) \right| = \left| \sum_{i}^{N} \lambda_i \right| \qquad (6)$$

where λ is a branch metric value for estimating a modulation level. Since the branch metric value is the difference (relative value) between an average carrier wave power and a received signal power, the dynamic range where a calculation is made can be reduced in comparison with the method for respectively calculating the sum of the average carrier wave power and the sum of the received signal power and for calculating their difference as represented by the equation (1).

As a result, computer resources in an actual system can be reduced.

[0085] Described above is the first modified embodiment of the present invention.

[0086] Additionally, in a current system, a received signal level is measured with signals such as an AGC signal, an RSSI signal, etc. For an actual communication, links are designed in consideration of a path loss. If received signal level errors are within a certain range, these information can be used as side information. For example, if a certain received signal level can be measured, there is no need to estimate all of modulation levels that a system sets by calculating the likelihood function values which correspond to the modulation level transmitted at the measured level and to the modulation levels to be transmitted at the levels preceding and succeeding the measured level. As a result, the total amount of computation can be reduced.

[0087] Described above is the second modified embodiment according to the first principle of the present invention.

[0088] Additionally, a system where a fading frequency is relatively small compared with symbol duration such as in a high-speed transmission can be configured so that, for example, up/down control (that is, an increment/decrement by 1 level) of a modulation level can be made. In this case, it is sufficient to consider only the modulation level changes in three states such as "±1" and "0" at each control timing of a modulation level. In such a system, a most recently estimated values is stored in a memory (or only an initial value is first stored, and thereafter, only the difference between the initial value and a newly estimated value is stored), and only the three states such as "±1" and "0" are recognized as currently estimated value for the stored estimated value, thereby reducing the total amount of computation.

[0089] Described above is the third modified embodiment according to the first principle of the present invention.

[0090] The present invention is a method for estimating the maximum likelihood value of a modulation level. If the present invention is considered to be integrated with a different maximum likelihood value determination method such as an error correction (including coded modulation) and a Viterbi algorithm for fading compensation (equalization, etc.), its adaptability is high. In such a system, if a conventional branch metric value (the distance between signal points) exceeds a certain threshold when an estimation is made at one modulation level, the total amount of computation can be reduced by suspending a subsequent calculation for this modulation level. Assuming that a 64QAM signal is sent and a QPSK signal is estimated, it is evident that the distance between signal points (of the most closest signal and the received signal) becomes significantly large upon receipt of a signal point with high power. In such a case, the number of estimation errors can be reduced by suspending the calculation operation based on the determination process including a determination of tolerance up to some degree.

[0091] Described above is the fourth modified embodiment according to first principle of the present invention.

[0092] Furthermore, the present invention is a technique for estimating a modulation level only with the information obtained on a receiving side, and uses no other control information, that is, no other transmission signals like one of the above described conventional techniques. Therefore, the present invention can be applied to a non-adaptive modulation system only by fixedly setting a modulation level. Namely, this means that the real coexistence of both of adaptive and non-adaptive modulation methods is realized in a system where both of the modulation methods coexist, and, for example, the adaptive modulation method is adopted only in one direction, while the maximum commonality can be obtained both at a base station and at a terminal in a system where the adaptive modulation method is adopted in both directions.

[0093] Described above is the fifth modified embodiment according to the first principle of the present invention.

<Preferred Embodiments According to the First Principle of the Present Invention>

[0094] Provided below is the explanation about the details of the preferred embodiments according to the first principle of the present invention.

[0095] In the following preferred embodiments, the adaptive modulation method for which any of a modulation level 2 (QPSK modulation method), a modulation level 4 (16QAM modulation method), a modulation level 6 (64QAM modulation method), and a modulation level 8 (256QAM modulation method) can possibly be selected is adopted.

[0096] Fig. 3 is a block diagram showing a first preferred embodiment according to the present invention, which corresponds to the principle of the configuration according to the present invention shown in Fig. 2.

[0097] A QPSK estimating unit 202, a 16QAM estimating unit 203, a 64 QAM estimating unit 204, and a 256 QAM estimating unit 205 calculate likelihood functions Λ_{QPSK}, Λ_{16QAM}, Λ_{64QAM}, and Λ_{256QAM} from a received signal frame 201 based on the above described equations (2) through (4) (also for the 256 QAM) for each of the modulation levels 2, 4, 6, and 8.

[0098] A QPSK demapper 206, a 16QAM demapper 207, a 64QAM demapper 208, and a 256QAM demapper 209 perform demodulation processes corresponding to the respective modulation levels, and temporarily store the demodulation results in N-delay circuits 211, 212, 213, and 214.

[0099] Then, a maximum likelihood function value selector 210 selects the likelihood function having the minimum value from among the likelihood functions Λ_{QPSK}, Λ_{16QAM}, Λ_{64QAM}, and Λ_{256QAM}, and makes a data selector 215 output as a demodulation signal the output of one of the N-delay circuits 211 through 214, which corresponds to the minimum value.

[0100] Fig. 4 exemplifies the format of a transmission signal sent from a transmitting side according to the preferred embodiment, and compares with the format of a conventional technique. For ease of explanation, a fading compensation control signal, etc. are omitted.

[0101] The transmission format of the conventional technique shown in Fig. 4A includes a modulation level signal ML every modulation level changing period (such as a normalized maximum fading frequency) in addition to an information signal I.

[0102] In the meantime, the transmission format according to the preferred embodiment shown in Fig. 4B includes not a modulation level signal but an information signal with the modulation level depending on a channel condition for each period determined by a system. By estimating a modulation level for each period described above (1 block=N symbols), demodulation (and decoding) can be performed without using a reference signal.

[0103] Fig. 5 shows the operations of the preferred embodiment illustrated in Fig. 3 when the number of symbols "N", which attains an estimation error rate allowed by a system, is smaller than the above described "L".

[0104] Since an estimation is made by using the likelihood function values calculated from symbols the number of which is smaller than "L" on a receiving side in this case, there is no need to perform calculations for all of the "L" symbols in one block. Additionally, an estimation accuracy which is relatively higher than that of a conventional system can be implemented if calculations are performed for all of the "L" symbols (when "N" is set to "L").

[0105] Fig. 6 shows the specific configuration of the circuits of the respective estimating units 202, 203, 204, and 205.

[0106] In the configuration shown in Fig. 6, a squaring circuit 501 calculates a received signal power value $r^2(i)$ by performing a square operation for the received signal $r(i)$ (i=1, 2, ..., N) output from a received signal detector 508 according to the above described equation (1).

[0107] Then, an accumulator composed of an adder 502 and a delay circuit 503 sequentially accumulates the received signal power value $r^2(i)$ output from the squaring circuit 501. This corresponds to the operation of the term E on the right side of the equation (1).

[0108] Next, the accumulated value is output from a switch 505 when an N symbol counter 504 counts N symbols for one block.

[0109] A subtractor 506 then subtracts the accumulated value from an average carrier wave power value P_{ML} (ML=QPSK, 16QAM, 64QAM, or 256QAM) of each modulation level. Additionally, an absolute value calculating circuit 507 calculates the absolute value of the resultant subtraction value, and outputs the calculated absolute value as a likelihood function Λ_{ML} (ML=QPSK, 16QAM, 64QAM, or 256 QAM).

[0110] Fig. 7 shows the configuration according to a second preferred embodiment, which implements the QPSK estimating unit 202, the 16QAM estimating unit 203, the 64QAM estimating unit 204, or the 256QAM estimating unit 2-5 shown in Fig. 3, according to the first preferred embodiment of the present invention. This figure shows a branch metric calculating module for estimating a modulation level. This configuration corresponds to the first modified embodiment according to the first principle of the present invention, which was referred to in the above described First Principle of the Present Invention.

[0111] With the configuration shown in Fig. 7, a subtractor 602 calculates a branch metric value λ_i by subtracting an average carrier wave power value P_{ML} (ML=QPSK, 16QAM, 64QAM, or 256QAM) of each modulation level from the received signal power value r^2 (i=1, 2, ..., N) output from a squaring circuit 601 according to the above described equation (6).

[0112] Next, an accumulator composed of an adder 603 and a delay circuit 604 sequentially accumulates the branch metric value λ_i output from the subtractor 602.

[0113] When an N-symbol counter 605 counts "N" symbols for one block, a switch 606 outputs the accumulated value.

[0114] An absolute value calculating circuit 607 calculates the absolute value of the accumulated value, and outputs the calculated absolute value as a likelihood function Λ_{ML} (ML=QPSK, 16QAM, 64QAM, or 256QAM).

[0115] With such a circuit configuration, the dynamic range of each circuit element can be reduced as described above.

[0116] Fig. 8 is a block diagram showing the configuration of a third preferred embodiment which employs an RSSI signal, according to the present invention. This configuration corresponds to the second modified emboldened according to the first principle of the present invention, which was referred to in the above described First Principle of the Present Invention. In this figure, the portions which relate to the first preferred embodiment and are denoted with the same reference numerals and symbols as those of Fig. 3 have the same capabilities as those of Fig. 3.

[0117] An RSSI signal indicates a received signal level. Normally, this signal is used not to measure an average power for one moment, which is referred to in this specification, but to measure an average received power for a longer period of time. Accordingly, this signal does not follow a fluctuation for one moment or a fluctuation occurring for a short period of time.

[0118] An RSSI measuring unit 702 coarsely estimates a modulation level at the time of a transmission by making a determination with a threshold, thereby reducing the estimation range of a modulation level.

[0119] In this sense, the estimated value of the modulation level obtained based on an RSSI signal can be also regarded as side information. By making both coarse and fine estimations as described above, a process load on a later

stage where a large amount of computation is performed can be reduced.

[0120] As shown in Fig. 8, if the RSSI measuring unit 702 measures, for example, the received signal level corresponding to the 16QAM modulation method, it provides a modulation level selector 701 with the selection signal ML_ SEL for instructing only the three units such as the 16QAM estimating unit 203, the QPSK estimating unit 202, and the 64QAM estimating unit 204 among the four estimating units 202 through 205 to run.

[0121] As a result, the modulation level selector 701 instructs only the above described three estimating units to run by providing a received signal frame 201.

[0122] In this way, the total amount of computation can be reduced to three-fourths in comparison with the case where the estimation range of a modulation level is not reduced.

[0123] Fig. 9 is a block diagram showing the configuration of a fourth preferred embodiment which employs an adaptive modulation method for performing up/down control of a modulation level, according to the present invention. This corresponds to the third modified embodiment according the first principle of the present invention, which was referred to in the First Principle of the Present Invention. In this figure, the portions which relate to the first preferred embodiment and are denoted with the same reference numerals and symbols as those of Fig. 3 have the same capabilities as those of Fig. 3.

[0124] In the configuration shown in Fig. 9, the most recently estimated value selected by the maximum likelihood function value selector 210 is stored in a most currently estimated value storing memory 803.

[0125] An estimation range selecting unit 802 recognizes only the three states such as "±1" and "0" based on the most recently estimated value stored in the most recently estimated value storing memory 803 to be currently estimated values.

[0126] As shown in Fig. 9, if the most recently estimated value stored in the most recently estimated value storing memory 803 is the value of the 16QAM modulation method, an estimated range selector 802 provides a modulation level selector 801 with the selection signal ML_SEL for instructing only the three estimating units such as the 16QAM estimating unit 203, the QPSK estimating unit 202, and the 64QAM estimating unit 204 among the four estimating units 202 through 205 to run.

[0127] As a result, the modulation level selector 801 instructs only the above described three estimating units to run by providing the received signal frame 201.

[0128] In this way, the total amount of computation can be reduced to three-fourths in comparison with the case where the estimation range of a modulation level is not reduced.

[0129] Fig. 10 shows the configuration of a fifth preferred embodiment which is a system combined with a decoder using a Viterbi decoding method. This corresponds to the fourth modified embodiment according to the first principle of the present invention. In this figure, the portions which relate to the first preferred embodiment and are denoted with the same reference numerals as those of Figs. 3 and 6 have the same capabilities as those of these figures. Although Fig. 10 illustrates only the portions relating to the QPSK modulation method, the other modulation methods have similar configurations.

[0130] In a Viterbi decoding algorithm, the likelihood value (branch metric value) $\mu(i)$ of a symbol is defined to be the square value of the distance between the vector r(i) detected by the received signal detector 508 and the signal point vector $r_{min}(i)$ closest thereto, that is, the following equation (7).

$$\mu(i) = (r(i) - r_{min}(i))^2 \qquad (7)$$

[0131] By way of example, as the likelihood value $\mu(i)$ of the QPSK modulation method, a distance calculator 901 calculates the square value of the distance between the vector r(i) detected by the received signal detector 508 and the signal point vector $r_{min}(i)$ output from the QPSK demapper 206, as shown in Fig. 10.

[0132] Since the likelihood value $\mu(i)$ is used also for a modulation level estimation in this preferred embodiment, the likelihood value $\mu_{ML}(i)$ of the modulation level ML is defined by the following equation.

$$\mu_{ML}(i) = (r(i) - r_{min}^{(ML)}(i))^2 \qquad (8)$$

[0133] If the following inequality (9) is satisfied regarding the threshold value E against the likelihood value $\mu_{ML}(i)$, or if the following inequality (10) is satisfied regarding the parametric value Γ_{ML} being an accumulated value of the branch metric value being the likelihood value $\mu_{ML}(i)$ against its corresponding threshold value E, the estimation and the decoding process for the corresponding modulation level is suspended.

$$\mu_{ML}(i) > \epsilon \qquad\qquad (9)$$

$$\Gamma_{ML} > E \qquad\qquad (10)$$

[0134] Note that the above described threshold value ϵ or E is determined based on the worst value of the Eb/No stipulated by the system according to the preferred embodiment of the present invention.

[0135] Here, assume that a QPSK signal is estimated when a 64QAM signal is transmitted. With the 64QAM modulation method, when the highest-power signal point r(i) is transmitted on the condition that no thermal noise exists, its coordinate will become, for example, (+7, +7). In the QPSK estimating unit 202, the signal point $r_{min}(i)$ closest to the above described signal point is (+1, +1). Accordingly, the likelihood value $\mu_{QPSK}(i)$ calculated for the QPSK modulation method is obtained as follows.

$$\mu_{QPSK}(i) = (7-1)^2 + (7-1)^2 = 72 \qquad\qquad (11)$$

[0136] As is known from Fig. 11, this likelihood value $\mu^{QPSK}(i)$ becomes 72, which is fairly larger than the distance between signal points (=2). In such a case, the estimation operation of the QPSK estimating unit 202 is suspended.

[0137] More specifically, a threshold detector 903 makes a comparison between the likelihood value $\mu(i)$ output from a distance calculator 902 or the accumulated value r obtained by accumulating the above described likelihood value μ (i), and the corresponding threshold value E or E. If the above described equation (9) or (10) is satisfied, the threshold detector 903 instructs the QPSK estimating unit 202 to suspend its operation.

[0138] With the above described configuration according to the fifth preferred embodiment of the present invention, the number of modulation level estimation errors can be reduced.

[0139] Fig. 12 shows the configuration of the system where a system using an adaptive modulation method being a prerequisite of the present invention, and a system using a non-adaptive modulation method coexist. This corresponds to the fifth modified embodiment according to the first principle of the present invention, which was referred to in the above described First Principle of the Present Invention.

[0140] With the configuration shown in Fig. 12, the systems which respectively use the adaptive and the non-adaptive modulation methods are configured as respective cells.

[0141] As described above, according to the present invention, there is no need to transmit a new control signal on a channel when a modulation level is changed, with an adaptive modulation method. Accordingly, the frame formats on the channel become exactly the same.

[0142] As a result, the system which can be applied to a non-adaptive modulation method by fixedly setting a modulation level, and which has no influence on a conventional system can be configured by preparing a base station and a terminal (mobile station) equipped with an adaptive modulation method according to the present invention.

[0143] Since the present invention is a technique closed only to a receiving side, receiver operations can be performed without being aware of the difference between systems. Namely, if a signal is transmitted by setting a modulation level to a fixed value on a transmitting side, an estimation result is always fixed to one particular modulation level also on a receiving side. Accordingly, the real coexistence of adaptive and non-adaptive modulation methods can be realized in the system where the adaptive modulation method is adopted to either of up- and down-links.

[0144] Additionally, the adaptive modulation system according to the present invention, can coexist with the non-adaptive modulation system, which does not require a feedback channel in, an FDD system having a channel on which the fading of an uplink does not correlate with that of a downlink, by being configured that signals are transmitted at the minimum modulation level (such as with the QPSK modulation method) if control information is not returned via a feedback channel (refer to 1508 shown in Fig. 1A) during a predetermined period of time after the transmission operations are performed.

[0145] Even in a system where the adaptive modulation method is adopted in both directions, the present invention still has an advantage that a common frame format can be used. Consequently, the commonality of an apparatus can be increased to its maximum in a dual mode system when a conventional system coexists (particularly at the time of a transition to a new system), and the effect of a reduction in the complexity of both a base station and a terminal (a reduction such as 1+1=1) can be expected.

<Second Principle of the Present Invention>

[0146]   Provided next is the explanation about a second principle of the present invention.

[0147]   With the adaptive modulation method according to the first principle of the present invention explained so far, the mean (primary moment) of a carrier wave power at each modulation level ML is used as a likelihood function Λ_{ML} as represented by the above described equation (1). In this case, a relatively high accuracy is required for the average value (absolute value) of a received signal level.

[0148]   Therefore, according to the second principle of the present invention, a comparison based on relative values can be made by using the variance of a carrier wave power being a secondary moment. As a result, an estimation with high accuracy can be made without using the mean (absolute value) of a received signal level itself.

[0149]   Specifically, the second principle of the present invention considers the variance (secondary moment) of the CNR at each modulation level.

[0150]   In a similar manner as in the case according to the first principle of the present invention, the average CNRs of modulation levels 2(QPSK), 4(16QAM), and 6 (64QAM) are respectively $\gamma_{QPSK} = \delta/\sigma^2$, $\gamma_{QPSK} = 5\delta/\sigma^2$, and $\gamma_{64QAM} = 21\delta/\sigma^2$. Here, 2δ is the (minimum) distance between signal points, and σ^2 is the variance of thermal noise. Additionally, the theoretical values of respective average bit error rates are calculated based on these average CNRs. As is known from these values, the average CNRs of the respective modulation levels differ from one another on the condition that the distance between signal points and the thermal noise, that is, Es/No are made identical, and the symbol error rates are made equal.

[0151]   However, since the mean or the sample mean are absolute values, these values are required to be accurate a matter of course. In the meantime, a variance is a scale for representing the distribution from an average value as a numerical value, which eliminates the need for learning the absolute value of the average value. Accordingly, even if a received signal level is not obtained with a high accuracy, it has no influence on the estimation accuracy of a transmitted modulation level.

[0152]   Here, assuming that the received signal point at a time point "i", its power is $r^2(i)$, which is defined to be a random variable x(i). According to the first principle of the present invention, the distance between the mean (primary moment) of the random variable x(i) defined by the following equation (12), and an average carrier wave power x_m is recognized to be a likelihood function value, as represented by the equation (1).

$$\overline{x(i)} = \frac{\Sigma_i^N r^2(i)}{N} \qquad (12)$$

[0153]   Here, assume that a state change period (hereinafter referred to as a block length), which is preset by a system, is "L", and the number of symbols (an estimation block length) "N" used for an estimation is equal to or smaller than "L" (that is, N(≤L)). At this time, the variance (secondary moment) of the signal points of the received signal is defined by the following equations (13) through (15).

$$\sigma^2 = E(x^2) - E^2(x) \qquad (13)$$

$$E(x^2) = \frac{\Sigma_i^N x^2(i)}{N} \qquad (14)$$

$$E^2(x) = \{\frac{\Sigma_i^N x(i)}{N}\}^2 \qquad (15)$$

[0154]   Specifically, according to the second principle of the present invention, the variance of a received signal power is measured by using as offset values the variance of the average carrier wave powers (P_{ML}) such as $\sigma^2 P_{QPSK} = 0.0$, $\sigma^2 P_{16QAM} = 16.0$, and $\sigma^2 P_{64QAM} = 336.0$ at the respective modulation levels when no thermal noise exists ($\sigma_N^2 \to 1$) and the distance between signal points is 2. At this time, the likelihood function Λ_{ML} of a modulation level (ML) is represented

by the following equation.

$$\Lambda_{ML} = |\sigma^2_{P_{ML}} - \sigma^2|$$ (16)

[0155] Accordingly, the likelihood functions Λ_{QPSK}, Λ_{16QAM}, and Λ_{64QAM} corresponding to the respective modulation functions are represented by the following equations.

$$\Lambda_{QPSK} = |\sigma^2_{P_{QPSK}} - \sigma^2|,$$ (17)

$$\Lambda_{16QPSK} = |\sigma^2_{P_{16QAM}} - \sigma^2|,$$ (18)

$$\Lambda_{64QAM} = |\sigma^2_{P_{64QAM}} - \sigma^2|,$$ (19)

[0156] According to the second principle of the present invention, the likelihood function having the minimum value among the likelihood functions Λ_{ML}s corresponding to respective modulation levels is used as an estimation result of a modulation level in a similar manner as in the case according to the first principle. Therefore, the principle of a system configuration is like the one shown in Fig. 2, similar to the configuration according to the first principle of the present invention.

[0157] Note that, however, according to the second principle of the present invention, the distributions of signal points at respective modulation levels are different when identical measurement symbols are used even if the variance of thermal noise is the same in a similar manner as in the case according to the first principle of the present invention. This is because the number of symbols must be set to a larger value with the increase of a modulation level in order to make the frequency of occurrence of all the signal points at a certain modulation level same when a random information source is assumed. For example, there is the following relationship between the reliability υ_{ML} of the variance of an average carrier wave power (mean) at respective modulations levels if the number of samples is "N", which are represented by the equations (17) through (19).

$$\upsilon_{QPSK} > \upsilon_{16QAM} > \upsilon_{64QAM}$$ (20)

[0158] This means that the present invention is based on Law of Large Numbers, and the reliability υ_{ML} of the variance of an average carrier wave power (mean) at each modulation level approaches "∞" and the sample variance $\sigma^2(N)$ approaches a true value, as "N" is set to a larger value.

[0159] As described above, according to the second principle of the present invention, each likelihood function value is calculated on the condition that the number of samples "N" is set to a same value. Therefore, two parameters such as the variance $\sigma^2 N$ of thermal noise (which is common to respective modulation levels), and the reliability υ_{ML} of the variance of the carrier wave power (mean) of each modulation level must be considered.

[0160] The former variance depends on Es/No, while the latter variance depends on a modulation level (particularly on the modulation level having a maximum transmission efficiency). Especially, for the latter variance, if a sufficient number of samples cannot be measured (if "N" is small), a transmission error (an irreducible error) can occur even if there is no thermal noise. As a matter of course, if the number of measurement samples is small although the former (used for a conventional Viterbi decoding algorithm as a model assumption) is large, an estimation accuracy degrades in a similar manner as in the case according to the first principle of the present invention.

[0161] Accordingly, according to the second principle of the present invention, an estimation error of a modulation level, which is caused by the above described interaction, can be prevented from occurring if the number of samples "N" is set to some large value, in a similar manner as in the case according to the first principle of the present invention.

[0162] When a system design is designed, the number of samples "N", which satisfies the allowable value of an

estimation error rate, is determined not only from the normalized maximum fading frequency viewpoint, but also from the block error rate (or the modulation level estimation error rate) viewpoint in a similar manner as in the case according to the first principle of the present invention.

[0163] By way of example, with the 64QAM modulation method having the maximum transmission efficiency among the above described combination of the modulation levels, the estimation error rate is increased to as high as approximately 4×10^{-4} when the number of symbols "N" is 50.

[0164] The above described number of symbols N=50 is the number equivalent to that of per pilot period (several tens of symbols), for example, if a transmission speed is lower than that of a pilot signal period "L" used for fading compensation. If the transmission speed is medium or high, the number of symbols becomes considerably smaller than that of per pilot period (several hundreds to several thousands of symbols).

[0165] That is, according to the second principle of the present invention, an estimation with a fairly high accuracy (errorless estimation) can be implemented particularly at a medium or a high speed if a modulation level is changed with the a pilot signal period, in a similar manner as in the case according to the first principle of the present invention.

[0166] Described above is the fundamentals of the first principle of the present invention.

[0167] Meanwhile, a likelihood function can be considered as a sample variance of N random variables $x_1, \ldots x_N$ as follows.

$$\overline{v} = \frac{(x_1 - \overline{x})^2 + \cdots + (x_N - \overline{x})^2}{N} \qquad (21)$$

where the sampling average x is:

$$\overline{x} = \frac{x_1 + \cdots + x_N}{N} \qquad (22)$$

[0168] Each of the random variables has the same mean and variance represented by the following equations.

$$E(x_i) = P_{ML}, \qquad (23)$$

$$\sigma_{xi}^2 = \sigma_{P_{ML}}^2 \qquad (24)$$

[0169] These variables do not correlate with one another, that is:

$$E(x(i) - P_{ML})(x(j) - P_{ML}) = 0 \qquad (25)$$

$$i \neq j \qquad (26)$$

[0170] The mean at this time is:

$$\mathbf{E}(\overline{v}) = \frac{N-1}{N}\sigma^2_{P_{ML}} \qquad (27)$$

[0171]   As a result, the distance between "N" sample variance $r_1, ..., r_N$ of received signals and the mean obtained by the above described equation (27) can be defined as a likelihood function value. Namely, an estimation accuracy can be improved by recognizing a received sequence as a random variable sequence in this way.

[0172]   To be more specific, the variance of a received signal power is measured by using as offset values a coefficient {(N-1)/N} based on the number of measurement sample "N" and the variance of average carrier wave powers (P_{ML}) such as $\sigma^2 P_{QPSK}=0.0$, $\sigma^2 P_{16QAH}=16.0$, and $\sigma^2 P_{64QAM}=336.0$ at respective modulation levels when no thermal noise exists ($\sigma_N^2 \rightarrow 1$) and the distance between signal points is 2. At this time, the likelihood function Λ_{ML} of a modulation level (ML) is represented by the following equation.

$$\Lambda^*_{ML} = \left| \frac{N-1}{N}\sigma^2_{P_{ML}} - \overline{v} \right| \qquad (28)$$

[0173]   Accordingly, the likelihood functions Λ_{QPSK}, Λ_{16QAM}, and Λ_{64QAM} corresponding to the respective modulation functions are represented by the following equations.

$$\Lambda^*_{QPSK} = \left| \frac{N-1}{N}\sigma^2_{P_{QPSK}} - \overline{v} \right|, \qquad (29)$$

$$\Lambda^*_{16QAM} = \left| \frac{N-1}{N}\sigma^2_{P_{16QAM}} - \overline{v} \right|, \qquad (30)$$

$$\Lambda^*_{64QAM} = \left| \frac{N-1}{N}\sigma^2_{P_{64QAM}} - \overline{v} \right|, \qquad (31)$$

[0174]   Described above is the first modified embodiment according to the second principle of the present invention. Also in this embodiment, the likelihood function having the minimum value among the likelihood functions Λ_{ML} corresponding to the respective modulation levels is used as an estimation result of a modulation level. Consequently, an estimation error rate can be decreased to 1.5×10^{-4}, approximately one-third of the rate obtained with a maximum likelihood estimation using the equations (17) through (19) based on the distribution of "N" symbols.

[0175]   Furthermore, a particular improvement can be made by using the offset implemented in the above described first modified embodiment for the calculation of the variance σ^2 based on the equations (13) through (15). Specifically, the likelihood function Λ_{ML} of each modulation level is obtained by the following equation.

$$\Lambda^{**}_{ML} = \left| \frac{N-1}{N}\sigma^2_{P_{ML}} - \sigma^2 \right| \qquad (32)$$

[0176]   Accordingly, the likelihood functions Λ_{QPSK}, Λ_{16QAM}, and Λ_{64QAM} are represented as follows.

$$\Lambda^{**}_{QPSK} = \left| \frac{N-1}{N}\sigma^2_{P_{QPSK}} - \sigma^2 \right|, \qquad (33)$$

$$\Lambda_{16QAM}^{**} = \left| \frac{N-1}{N}\sigma_{P_{16QAM}}^2 - \sigma^2 \right|, \qquad (34)$$

$$\Lambda_{64QAM}^{**} = \left| \frac{N-1}{N}\sigma_{P_{64QAM}}^2 - \sigma^2 \right|, \qquad (35)$$

[0177] Described above is the second modified embodiment according to the second principle of the present invention. As a result, an estimation error rate can be decreased to 3×10^{-4}, approximately three-fourths of the rate obtained with a maximum likelihood estimation using the equations (17) through (19) based on the variance of "N" symbols.

<Preferred Embodiments According to the Second Principle of the Present Invention>

[0178] Provided below is the explanation about the details of preferred embodiments according to the second principle of the present invention.

[0179] As the fundamental configurations of the following sixth to eighth preferred embodiments, the above described configurations (shown in Figs. 3, 8, 9, and 19) of the first to fifth preferred embodiments according to the first principle of the present invention can be adopted.

[0180] Fig. 13 shows the configuration of a sixth preferred embodiment according to the present invention, which implements the QPSK estimating unit 202, the 16QAM estimating unit 203, the 64QAM estimating unit 204, or the 256QAM estimating unit 205, which are shown in Fig. 3, 8, 9, or 10. This is the preferred embodiment according to the second principle of the present invention.

[0181] In Fig. 13, squaring circuits 1201, 1202, and 1205, accumulators 1203 and 1204, a subtractor 1207, and dividers 1206 and 1208 calculate the distribution of a received signal point based on the above described equations (13) through (15).

[0182] A subtractor 1209 calculates the internal terms representing an absolute value on the right side of the equation (16).

[0183] An absolute value calculating circuit 1210 performs an absolute value calculation on the right side of the equation (16), and outputs a likelihood function value Λ_{ML}.

[0184] Fig. 14 shows the configuration of a seventh preferred embodiment according to the present invention, which implements the QPSK estimating unit 202, the 16QAM estimating unit 203, the 64QAM estimating unit 204, or the 256QAM estimating unit 205, which are shown in Fig. 3, 8, 9, or 10. This corresponds to the first modified embodiment according to the second principle of the present invention.

[0185] In Fig. 14, a squaring circuit 1301, an accumulator 1302, and a divider 1301 calculates a sample mean based on the above described equation (22). A subtractor 1304, a squaring circuit 1305, and a divider 1306 calculates a sample variance based on the equation (21).

[0186] A subtractor 1307 calculates the internal terms representing an absolute value on the right side of the equation (28).

[0187] An absolute value calculating circuit 1308 performs an absolute value calculation on the right side of the equation (28), and outputs a likelihood function value Λ_{ML}.

[0188] Fig. 15 shows the configuration of an eighth preferred embodiment according to the present invention, which implements the QPSK estimating unit 202, the 16QAM estimating unit 203, the 64QAM estimating unit, or the 256QAM estimating unit 205, which are shown in Fig. 3, 8, 9, or 10. This corresponds to the second modified embodiment according to the second principle of the present invention.

[0189] In Fig. 15, squaring circuits 1201, 1202, and 1205, accumulators 1203 and 1204, a subtractor 1207, and dividers 1206 and 1208 are similar to those shown in Fig. 13. That is, they calculate the variance of a received signal point based on the above described equations (13) through (15). A subtractor 1401 calculates the internal terms representing an absolute value on the right side of the equation (32).

[0190] An absolute value calculating circuit 1402 performs an absolute value calculation on the right side of the equation (32), and outputs a likelihood function value Λ_{ML}.

Claims

1. A radio transmission method for adaptively changing a modulation level according to a channel condition comprising

the step of:

calculating a mean of a carrier wave power for a received signal to which no modulation level information is added when being transmitted;
the method further comprising the steps of

calculating as a likelihood value of each modulation level a difference between the calculated mean of the carrier wave power of the received signal, and a mean of the carrier wave power, which is prescribed for each modulation level; and
estimating as a modulation level of the received signal a modulation level corresponding to a maximum likelihood value among likelihood values of respective modulation levels;

wherein calculating the likelihood value of each modulation level includes

calculating the absolute value of a difference between the prescribed carrier wave power mean P_{ML} multiplied by the number of received symbols N, and the accumulated sum of quare values $r^2(i)$ of the received symbols, where i is the received symbol index; or
calculating the absolute value of the accumulated sum of the differences between the prescribed carrier wave power mean P_{ML} and the square value $r^2(i)$ of each received symbol.

2. The radio transmission method according to claim 1, further comprising the step of:

reducing an absolute value of the likelihood value by performing a likelihood value calculation for each received symbol.

3. The radio transmission method according to claim 1, further comprising the step of:

setting an estimation block length of a signal transmitted at a same modulation level according to an estimation error rate allowed by a system.

4. The radio transmission method according to claim 1, further comprising the steps of:

obtaining a received signal level; and
restricting a range of a modulation level for which the likelihood value is calculated based on the received signal level.

5. The radio transmission method according to claim 1, further comprising the step of:

restricting a range of a modulation level for which the likelihood value is calculated when a current estimation is made, based on a modulation level which is most recently estimated.

6. The radio transmission method according to claim 1, further comprising the step of:

suspending a subsequent estimation operation of the likelihood value for a corresponding modulation level if a distance between signal points exceeds a certain threshold.

7. The radio transmission method according to claim 1, further comprising the step of:

implementing a non-adaptive modulation method by fixedly setting a modulation level when being transmitted.

8. A radio transmission method for adaptively changing a modulation level according to a channel condition, comprising the step of:

calculating a variance of a carrier wave power for a received signal to which no modulation level information is added when being transmitted;
the method further comprising the steps:

calculating as a likelihood value of each modulation level a difference between the calculated variance of

the carrier wave power of the received signal, and a variance of the carrier wave power, which is prescribed for each modulation level; and

estimating as a modulation level of the received signal a modulation level corresponding to a maximum likelihood value among likelihood values of respective modulation levels;

wherein calculating the likelihood value of each modulation level includes calculating the absolute value of a difference between the prescribed carrier wave power variance $\sigma^2_{P_{ML}}$ and the calculated variance of the carrier wave power of the received signal, i.e.

$$\frac{\sum_i^N x^2(i)}{N} - \left(\frac{\sum_i^N x(i)}{N}\right)^2 ,$$

wherein N is the number of received symbols, $x(i)$ is the squared value $r^2(i)$ of a received symbol, and i is the received symbol index.

9. The radio transmission method according to claim 8, further comprising the step of:

setting an estimation block length of a signal transmitted at a same modulation level according to an estimation error rate allowed by a system.

10. The radio transmission method according to claim 8, further comprising the steps of:

obtaining a received signal level; and
restricting a range of a modulation level for which the likelihood value is calculated based on the received signal level.

11. The radio transmission method according to claim 8, further comprising the step of:

restricting a range of a modulation level for which the likelihood value is calculated when a current estimation is made, based on a modulation level which is most recently estimated.

12. The radio transmission method according to claim 8, further comprising the step of:

suspending a subsequent estimation operation of the likelihood value at a corresponding modulation level if a distance between signal points exceeds a certain threshold.

13. The radio transmission method according to claim 8, further comprising the step of:

implementing a non-adaptive modulation method by fixedly setting a modulation level when being transmitted.

14. A radio transmission method according to claim 8, wherein
the variance of the carrier wave power of the received signal is a sample variance.

15. A radio transmission method according to claim 8, wherein
the variance of the carrier wave power, which is prescribed for each modulation level is a sample variance.

16. A radio transmission apparatus for adaptively changing a modulation level according to a channel condition, comprising:

a circuit for calculating a mean value of a carrier wave power for a received signal (101, 201) to which no modulation level information is added when being transmitted;
the apparatus further comprising:

a circuit (102#1 to 102#N, 202 to 205) for calculating as a likelihood value of each modulation level a difference between the calculated mean value of the carrier wave power of the received signal, and a mean value of the carrier wave power, which is prescribed for each modulation level; and
a circuit (104, 210) for estimating as a modulation level of the received signal a modulation level corresponding to a maximum likelihood value among likelihood values of respective modulation levels;

wherein the circuit (102#1 to 102#N, 202 to 205) for calculating the likelihood value of each modulation level is configured for

calculating the absolute value of a difference between the prescribed carrier wave power mean P_{ML} multiplied by the number of received symbols N, and the accumulated sum of square values $r^2(i)$ of the received symbols, where i is the received symbol index; or for
calculating the absolute value of the accumulated sum of the differences between the prescribed carrier wave power mean P_{ML} and the square value $r^2(i)$ of each received symbol.

17. The radio transmission apparatus according to claim 16, further comprising for each modulation level:

a circuit (601) for calculating a square value of each received symbol;
a circuit (602) for subtracting the mean value of the carrier wave power, which is prescribed for a corresponding modulation level, from the square value;
a circuit (603 to 606) for accumulating a subtraction result by a predetermined number of symbols; and
a circuit (607) for calculating an absolute value of an accumulation result, and for outputting a calculation result as a likelihood value of the corresponding modulation level.

18. The radio transmission apparatus according to claim 16, wherein
an estimation block length of a signal transmitted at a same modulation level is set according to an estimation error rate allowed by a system.

19. The radio transmission apparatus according to claim 16, further comprising:

a circuit (702) for obtaining a received signal level; and
a circuit (701) for restricting a range of a modulation level for which the likelihood value is calculated, based on the received signal level.

20. The radio transmission apparatus according to claim 16, further comprising:

a circuit (803) for storing a modulation level which is most recently estimated; and
a circuit (801, 802) for restricting a range of a modulation level for which the likelihood value is calculated when a current estimation is made, based on the stored modulation level which is most recently estimated.

21. The radio transmission apparatus according to claim 16, further comprising:

a circuit (901 to 903) for suspending a subsequent estimation operation of the likelihood value for a corresponding modulation level if a distance between signal points exceeds a certain threshold.

22. A radio transmission apparatus for adaptively changing a modulation level according to a channel condition, comprising:

a circuit (1201 to 1208) for calculating a variance value of a carrier wave power for a received signal to which no modulation level information is added when being transmitted;
the apparatus further comprising:

a circuit (1209, 1210) for calculating as a likelihood value of each modulation level a difference between the calculated variance value of the carrier wave power of the received signal, and a variance value of the carrier wave power, which is prescribed for each modulation level; and
a circuit (210) for estimating as a modulation level of the received signal a modulation level corresponding to a maximum likelihood value among likelihood values of respective modulation levels;

wherein the circuit (1209, 1210) for calculating the likelihood value of each modulation level is configured for calculating the absolute value of a difference between the prescribed carrier wave power variance $\sigma^2_{P_{ML}}$ and the calculated variance of the carrier wave power of the received signal, i.e.

$$\frac{\sum_i^N x^2(i)}{N} - \left(\frac{\sum_i^N x(i)}{N}\right)^2 ,$$

wherein N is the number of received symbols, $x(i)$ is the squared value $r^2(i)$ of a received symbol, and i is the received symbol index.

23. The radio transmission apparatus according to claim 22, wherein
an estimation block length of a signal transmitted at a same modulation level is set according to an estimation error rate allowed by a system.

24. The radio transmission apparatus according to claim 22, further comprising:

    a circuit (702) for obtaining a received signal level; and
    a circuit (701) for restricting a range of a modulation level for which the likelihood value is calculated based on the received signal level.

25. The radio transmission apparatus according to claim 22, further comprising:

    a circuit (803) for storing a modulation level which is most recently estimated; and
    a circuit (801, 802) for restricting a range of a modulation level for which the likelihood value is calculated when a current estimation is made, based on the stored modulation level which is most recently estimated.

26. The radio transmission apparatus according to claim 22, further comprising:

    a circuit (901 to 903) for suspending a subsequent estimation operation of the likelihood value for a corresponding modulation level if a distance between signal points exceeds a certain threshold.

27. A radio transmission apparatus according to claim 22, wherein
the circuit (1201 to 1208) for calculating a variance value of a carrier wave power for received signals is a circuit for calculating a sample variance value.

28. A radio transmission apparatus according to claim 22, wherein
the variance value of the carrier wave power, which is prescribed for each modulation level is a sample variance.

Patentansprüche

1. Ein Funkübertragungsverfahren zum adaptiven Ändern eines Modulationsniveaus gemäß einer Kanalbedingung, umfassend den Schritt:

    Berechnen eines Mittels einer Trägerwellenleistung für ein empfangenes Signal, an das keine Modulationsniveauinformation hinzugefügt wird, wenn es übertragen wird;

    wobei das Verfahren ferner die Schritte umfasst:

    Berechnen als Wahrscheinlichkeitswert von jedem Modulationsniveau eines Unterschieds zwischen dem berechneten Mittel der Trägerwellenleistung des empfangenen Signals, und einem Mittel der Trägerwellenleistung, die für jedes Modulationsniveau vorgeschrieben ist; und

Schätzen als Modulationsniveau des empfangenen Signals eines Modulationsniveaus entsprechend einem maximalen Wahrscheinlichkeitswert von Wahrscheinlichkeitswerten der entsprechenden Modulationsniveaus;

wobei Berechnen des Wahrscheinlichkeitswerts von jedem Modulationsniveau enthält

Berechnen des Absolutwerts eines Unterschieds zwischen dem vorgeschriebenen Trägerwellenleistungsmittel P_{ML}, multipliziert mit der Anzahl der empfangenen Symbole N, und der gesammelten Summe von quadratischen Werten $r^2(i)$ der empfangenen Symbole, wobei i der empfangene-Symbolindex ist; oder

Berechnen des Absolutwerts der gesammelten Summe der Unterschiede zwischen dem vorgeschriebenen Trägerwellenleistungsmittel P_{ML} und dem quadratischen Wert $r^2(i)$ von jedem empfangenen Symbol.

2. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend den Schritt:

Verringern eines Absolutwerts des Wahrscheinlichkeitswerts durch Ausführen einer Wahrscheinlichkeitswertsberechnung für jedes empfangene Symbol.

3. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend den Schritt:

Einstellen einer Abschätzungsblocklänge eines Signals, das übertragen wird bei einem gleichen. Modulationsniveau gemäß einer Abschätzungsfehlerrate, die durch ein System erlaubt ist.

4. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend die Schritte:

Erhalten eines empfangenen Signalniveaus; und
Beschränken eines Bereichs eines Modulationsniveaus, für das der Wahrscheinlichkeitswert berechnet wird auf Grundlage des empfangenen-Signalniveaus.

5. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend den Schritt:

Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird, wenn eine momentane Abschätzung durchgeführt wird auf Grundlage eines Modulationsniveaus, das zuletzt geschätzt wurde.

6. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend den Schritt:

Unterbrechen eines nachfolgenden Abschätzungsbetriebs des Wahrscheinlichkeitswerts für ein entsprechendes Modulationsniveau, falls ein Abstand zwischen Signalpunkten einen gewissen Schwellenwert überschreitet.

7. Das Funkübertragungsverfahren nach Anspruch 1, ferner umfassend den Schritt:

Implementieren eines nicht-adaptiven Modulationsverfahrens durch festes Einstellen eines Modulationsniveaus bei Übertragung.

8. Ein Funkübertragungsverfahren zum Adaptiven Ändern eines Modulationsniveaus gemäß einer Kanalbedingung, umfassend den Schritt:

Berechnen einer Varianz einer Trägerwellenleistung für ein empfangenes Signal, an das keine Modulationsniveauinformation hinzugefügt wird, wenn es übertragen wird;
das Verfahren ferner umfassend die Schritte:

Berechnen als ein Wahrscheinlichkeitswert von jedem Modulationsniveau eines Unterschieds zwischen der berechneten Varianz der Trägerwellenleistung des empfangenen Signals; und einer Varianz der Trägerwellenleistung, die für jedes Modulationsniveau vorgeschrieben ist; und
Abschätzen als Modulationsniveau des empfangenen Signals eines Modulationsniveaus entsprechend einem maximalen Wahrscheinlichkeitswert von Wahrscheinlichkeitswerten der entsprechenden Modulationsniveaus;

wobei Berechnen des Wahrscheinlichkeitswerts von jedem Modulationsniveau enthält Berechnen des Absolutwerts

eines Unterschieds zwischen der vorgeschriebenen Trägerwellenleistungsvarianz $\sigma^2 P_{ML}$ und der berechneten Varianz der Trägerwellenleistung des empfangenen Signals, das heißt,

$$\frac{\sum_i^N \chi^2(i)}{N} - \left(\frac{\sum_i^N \chi(i)}{N}\right)^2 ,$$

wobei N die Anzahl der empfangenen Symbole ist, $\chi(i)$ der quadratische Wert $r^2(i)$ eines empfangenen Symbols ist, und i der empfangene Symbolindex ist.

9. Das Funkübertragungsverfahren nach Anspruch 8, ferner umfassend den Schritt:

    Einstellen einer Abschätzungsblocklänge eines Signals, das übertragen wird mit einem gleichen Modulationsniveau gemäß einer Abschätzungsfehlerrate, die von einem System erlaubt ist.

10. Das Funkübertragungsverfahren nach Anspruch 8, ferner umfassend die Schritte:

    Erhalten eines empfangenen-Signalniveaus; und
    Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird auf Grundlage des empfangenen-Signalniveaus.

11. Das Funkübertragungsverfahren nach Anspruch 8, ferner umfassend den Schritt:

    Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird, wenn eine momentane Abschätzung durchgeführt wird auf Grundlage eines Modulationsniveaus, das zuletzt geschätzt wurde.

12. Das Funkübertragungsverfahren nach Anspruch 8, ferner umfassend den Schritt:

    Unterbrechen eines nachfolgenden Abschätzungsbetriebs des Wahrscheinlichkeitswerts bei einem entsprechenden Modulationsniveau, falls ein Abstand zwischen Signalpunkten einen gewissen Schwellenwert überschreitet.

13. Das Funkübertragungsverfahren nach Anspruch 8, ferner umfassend den Schritt:

    Implementieren eines nicht-adaptiven Modulationsverfahrens durch festes Einstellen eines Modulationsniveaus bei Übertragung.

14. Ein Funkübertragungsverfahren nach Anspruch 8, wobei die Varianz der Trägerwellenleistung des empfangenen Signals eine Abtastvarianz ist.

15. Ein Funkübertragungsverfahren nach Anspruch 8, wobei
die Varianz der Trägerwellenleistung, die für jedes Modulationsniveau vorgeschrieben ist, eine Abtastvarianz ist.

16. Ein Funkübertragungsvorrichtung zum adaptiven Ändern eines Modulationsniveaus gemäß einer Kanalbedingung, umfassend:

    eine Schaltung zum Berechnen eines Mittelwerts einer Trägerwellenleistung für ein empfangenes Signal (101, 201), an das keine Modulationsniveauinformation hinzugefügt wird, wenn es übertragen wird;
    die Vorrichtung ferner umfassend:

        eine Schaltung (102#1 bis 102#N, 202 bis 205) zum Berechnen als einen Wahrscheinlichkeitswert von jedem Modulationsniveau eines Unterschieds zwischen dem berechneten Mittelwert der Trägerwellenleistung des empfangenen Signals, und einem Mittelwert der Trägerwellenleistung, die vorgeschrieben ist für jedes Modulationsniveau; und

eine Schaltung (104, 210) zum Abschätzen als ein Modulationsniveau des empfangenen Signals eines Modulationsniveaus entsprechend einem maximalen Wahrscheinlichkeitswert von Wahrscheinlichkeitswerten von entsprechenden Modulationsniveaus;

wobei die Schaltung (102#1 bis 102#N, 202 bis 205) zum Berechnen des Wahrscheinlichkeitswerts von jedem Modulationsniveau konfiguriert ist zum

Berechnen des Absolutwerts eines Unterschieds zwischen dem vorgeschriebenen Trägerwellenleistungsmittel P_{ML}, multipliziert mit der Anzahl der empfangenen Symbole N, und der gesammelten Summe von quadratischen Werten $r^2(i)$ der empfangenen Symbole, wobei i der empfangene-Symbolindex ist; oder zum
Berechnen des Absolutwerts der gesammelten Summe der Unterschiede zwischen dem vorgeschriebenen Trägerwellenleistungsmittel P_{ML} und dem quadratischen Wert $r^2(i)$ von jedem empfangenen Symbol.

17. Die Funkübertragungsvorrichtung nach Anspruch 16, ferner umfassend für jedes Modulationsniveau;
eine Schaltung (601) zum Berechnen eines quadratischen Werts von jedem empfangenen Symbol;
eine Schaltung (602) zum Subtrahieren des Mittelwerts der Trägerwellenleistung, der vorgeschrieben ist für ein entsprechendes Modulationsniveau, von dem quadratischen Wert;
eine Schaltung (603 bis 606) zum Sammeln eines Subtraktionsergebnis durch eine vorbestimmte Anzahl von Symbolen; und
eine Schaltung (607) zum Berechnen eines Absolutwerts eines Sammelergebnisses und zum Ausgeben eines Berechnungsergebnisses als einen Wahrscheinlichkeitswert des entsprechenden Modulationsniveaus.

18. Die Funkübertragungsvorrichtung nach Anspruch 16, wobei
eine Abschätzungsblocklänge eines Signals, das übertragen wird mit einem gleichen Modulationsniveau, eingestellt wird gemäß einer Abschätzungsfehlerrate, die von einem System erlaubt ist.

19. Die Funkübertragungsvorrichtung nach Anspruch 16, ferner umfassend:

eine Schaltung (702) zum Erhalten eines empfangenen-Signalniveaus; und
eine Schaltung (701) zum Beschränken eines Bereichs eines Modulationsniveaus, für das der Wahrscheinlichkeitswert berechnet wird auf Grundlage des empfangenen-Signalniveaus.

20. Die Funkübertragungsvorrichtung nach Anspruch 16, ferner umfassend:

eine Schaltung (803) zum Speichern eines Modulationsniveaus, das zuletzt abgeschätzt wurde; und
eine Schaltung (801, 802) zum Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird, wenn eine momentane Abschätzung durchgeführt wird auf Grundlage des gespeicherten Modulationsniveaus, das zuletzt abgeschätzt wurde.

21. Die Funkübertragungsvorrichtung nach Anspruch 16, ferner umfassend:

eine Schaltung (901 bis 903) zum Unterbrechen eines nachfolgenden Abschätzungsbetriebs des Wahrscheinlichkeitswerts für ein entsprechendes Modulationsniveau, falls ein Abstand zwischen Signalpunkten einen gewissen Schwellenwert überschreitet.

22. Eine Funkübertragungsvorrichtung zum adaptiven Ändern eines Modulationsniveaus gemäß einer Kanalbedingung, umfassend:

eine Schaltung (1201 bis 1208) zum Berechnen eines Varianzwerts einer Trägerwellenleistung für ein empfangenes Signal, an das keine Modulationsniveauinformation hinzugefügt wird, wenn es übertragen wird;
die Vorrichtung ferner umfassend:

eine Schaltung (1209, 1210) zum Berechnen als einen Wahrscheinlichkeitswert von jedem Modulationsniveau eines Unterschieds zwischen dem berechneten Varianzwert der Trägerwellenleistung des empfangenen Signals, und einem Varianzwert der Trägerwellenleistung, die für jedes Modulationsniveau vorgeschrieben ist; und
eine Schaltung (210) zum Abschätzen als Modulationsniveau des empfangenen Signals eines Modulationsniveaus entsprechend einem maximalen Wahrscheinlichkeitswert von Wahrscheinlichkeitswerten der

entsprechenden Modulationsniveaus;

wobei die Schaltung (1209, 1210) zum Berechnen des Wahrscheinlichkeitswerts von jedem Modulationsniveau konfiguriert ist zum Berechnen des Absolutwerts eines Unterschieds zwischen der vorgeschriebenen Trägerwellenleistungsvarianz $\sigma^2 P_{ML}$ und der berechneten Varianz der Trägerwellenleistung des empfangenen Signals, das heißt,

$$\frac{\sum_{i}^{N} \chi^2(i)}{N} - \left(\frac{\sum_{i}^{N} \chi(i)}{N}\right)^2,$$

wobei N die Anzahl der empfangenen Symbole ist, $\chi(i)$ der quadratische Wert $r^2(i)$ eines empfangenen Symbols ist, und i der empfangene Symbolindex ist.

23. Die Funkübertragungsvorrichtung nach Anspruch 22, wobei
eine Abschätzungsblocklänge eines Signals, das übertragen wird mit einem gleichen Modulationsniveau, eingestellt ist gemäß einer Abschätzungsfehlerrate, die von einem System erlaubt ist.

24. Die Funkübertragungsvorrichtung nach Anspruch 22, ferner umfassend:

eine Schaltung (702) zum Erhalten eines empfangenen-Signalniveaus; und
eine Schaltung (701) zum Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird auf Grundlage des empfangenen-Signalniveaus.

25. Die Funkübertragungsvorrichtung nach Anspruch 22, ferner umfassend:

eine Schaltung (803) zum Speichern eines Modulationsniveaus, das zuletzt abgeschätzt wurde; und
eine Schaltung (801, 802) zum Beschränken eines Bereichs eines Modulationsniveaus, für den der Wahrscheinlichkeitswert berechnet wird, wenn eine momentane Abschätzung durchgeführt wird auf Grundlage des gespeicherten Modulationsniveaus, das zuletzt abgeschätzt wurde.

26. Die Funkübertragungsvorrichtung nach Anspruch 22, ferner umfassend:

eine Schaltung (901 bis 903) zum Unterbrechen eines nachfolgenden Abschätzungsbetriebs des Wahrscheinlichkeitswerts für ein entsprechendes Modulationsniveau, falls ein Abstand zwischen Signalpunkten einen gewissen Schwellenwert überschreitet.

27. Eine Funkübertragungsvorrichtung nach Anspruch 22, wobei
die Schaltung (1201 bis 1208) zum Berechnen eines Varianzwerts einer Trägerwellenleistung für empfangene Signale eine Schaltung zum Berechnen eines Abtastvarianzwerts ist.

28. Eine Funkübertragungsvorrichtung nach Anspruch 22, wobei
der Varianzwert der Trägerwellenleistung, der für jedes Modulationsniveau vorgeschrieben ist, eine Abtastvarianz ist.

Revendications

1. Procédé d'émission par radio destiné à changer de façon adaptative un niveau de modulation en fonction de l'état d'une voie, comprenant l'étape :

de calcul d'une moyenne d'une puissance d'onde porteuse pour un signal reçu auquel aucune information de niveau de modulation n'est ajoutée lorsqu'il est émis ;
le procédé comprenant en outre les étapes :

de calcul, comme valeur de vraisemblance de chaque niveau de modulation, d'une différence entre la

moyenne calculée de la puissance d'onde porteuse du signal reçu et une moyenne de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation ; et

d'estimation, comme niveau de modulation du signal reçu, d'un niveau de modulation correspondant à une valeur de vraisemblance maximale parmi des valeurs de vraisemblance de niveaux respectifs de modulation ;

dans lequel le calcul de la valeur de vraisemblance de chaque niveau de modulation inclut :

le calcul de la valeur absolue d'une différence entre la moyenne imposée P_{ML} de puissance d'onde porteuse multipliée par le nombre N de symboles reçus, et de la somme cumulée des valeurs au carré $r^2(i)$ des symboles reçus, où i est l'indice de symbole reçu ; ou

le calcul de la valeur absolue de la somme cumulée des différences entre la moyenne imposée P_{ML} de puissance d'onde porteuse et la valeur au carré $r^2(i)$ de chaque symbole reçu.

2. Procédé d'émission par radio selon la revendication 1, comprenant en outre l'étape :

de réduction d'une valeur absolue de la valeur de vraisemblance en effectuant un calcul de valeur de vraisemblance pour chaque symbole reçu.

3. Procédé d'émission par radio selon la revendication 1, comprenant en outre l'étape :

de fixation d'une longueur de bloc d'estimation d'un signal émis à un même niveau de modulation en fonction d'un taux d'erreurs d'estimation admis par un système.

4. Procédé d'émission par radio selon la revendication 1, comprenant en outre les étapes :

d'obtention d'un niveau de signal reçu ; et

de limitation, en se basant sur le niveau de signal reçu, de la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée.

5. Procédé d'émission par radio selon la revendication 1, comprenant en outre l'étape :

de limitation, en se basant sur un niveau de modulation qui a été estimé le plus récemment, de la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée lorsqu'une estimation actuelle a été faite.

6. Procédé d'émission par radio selon la revendication 1, comprenant en outre l'étape :

de suspension d'une opération ultérieure d'estimation de la valeur de vraisemblance pour un niveau de modulation correspondant si une distance entre des points de signal excède un certain seuil.

7. Procédé d'émission par radio selon la revendication 1, comprenant en outre l'étape :

de mise en oeuvre d'un procédé non adaptatif de modulation en fixant de manière immuable un niveau de modulation lorsqu'il est émis.

8. Procédé d'émission par radio destiné à changer de façon adaptative un niveau de modulation en fonction de l'état d'une voie, comprenant l'étape :

de calcul d'une variance d'une puissance d'onde porteuse pour un signal reçu auquel aucune information de niveau de modulation n'est ajoutée lorsqu'il est émis ;
le procédé comprenant en outre les étapes :

de calcul, comme valeur de vraisemblance de chaque niveau de modulation, d'une différence entre la variance calculée de la puissance d'onde porteuse du signal reçu et une variance de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation ; et

d'estimation, comme niveau de modulation du signal reçu, d'un niveau de modulation correspondant à une valeur de vraisemblance maximale parmi des valeurs de vraisemblance de niveaux respectifs de

modulation ;

dans lequel le calcul de la valeur de vraisemblance de chaque niveau de modulation inclut le calcul de la valeur absolue d'une différence entre la variance imposée $\sigma^2_{P_{ML}}$ de puissance d'onde porteuse et la variance calculée de la puissance d'onde porteuse du signal reçu, c'est-à-dire :

$$\frac{\sum_i^N x^2(i)}{N} - \left(\frac{\sum_i^N x(i)}{N}\right)^2$$

où N est le nombre de symboles reçus, x(i) est la valeur au carré $r^2(i)$ d'un symbole reçu, et i est l'indice de symbole reçu.

9. Procédé d'émission par radio selon la revendication 8, comprenant en outre l'étape :

    de fixation d'une longueur de bloc d'estimation d'un signal émis à un même niveau de modulation en fonction d'un taux d'erreurs d'estimation admis par un système.

10. Procédé d'émission par radio selon la revendication 8, comprenant en outre les étapes :

    d'obtention d'un niveau de signal reçu ; et
    de limitation, en se basant sur le niveau de signal reçu, de la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée.

11. Procédé d'émission par radio selon la revendication 8, comprenant en outre l'étape :

    de limitation, en se basant sur un niveau de modulation qui a été estimé le plus récemment, de la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée lorsqu'une estimation actuelle a été faite.

12. Procédé d'émission par radio selon la revendication 8, comprenant en outre l'étape :

    de suspension d'une opération ultérieure d'estimation de la valeur de vraisemblance à un niveau de modulation correspondant si une distance entre des points de signal excède un certain seuil.

13. Procédé d'émission par radio selon la revendication 8, comprenant en outre l'étape :

    de mise en oeuvre d'un procédé non adaptatif de modulation en fixant de manière immuable un niveau de modulation lorsqu'il est émis.

14. Procédé d'émission par radio selon la revendication 8, dans lequel :

    la variance de la puissance d'onde porteuse du signal reçu est une variance d'échantillons.

15. Procédé d'émission par radio selon la revendication 8, dans lequel :

    la variance de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation est une variance d'échantillons.

16. Appareil d'émission par radio destiné à changer de façon adaptative un niveau de modulation en fonction de l'état d'une voie, comprenant l'étape :

    un circuit destiné à calculer une valeur moyenne d'une puissance d'onde porteuse pour un signal reçu (101, 201) auquel aucune information de niveau de modulation n'est ajoutée lorsqu'il est émis ;

l'appareil comprenant en outre :

un circuit (102#1 à 102#N, 202 à 205) destiné à calculer, comme valeur de vraisemblance de chaque niveau de modulation, une différence entre la valeur moyenne calculée de la puissance d'onde porteuse du signal reçu et une valeur moyenne de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation ; et
un circuit (104, 210) destiné à estimer, comme niveau de modulation du signal reçu, un niveau de modulation correspondant à une valeur de vraisemblance maximale parmi des valeurs de vraisemblance de niveaux respectifs de modulation ;

dans lequel le circuit (102#1 à 102#N, 202 à 205) destiné à calculer la valeur de vraisemblance de chaque niveau de modulation est configuré :

pour calculer la valeur absolue d'une différence entre la moyenne imposée P_{ML} de puissance d'onde porteuse multipliée par le nombre N de symboles reçus, et la somme cumulée des valeurs au carré $r^2(i)$ des symboles reçus, où i est l'indice de symbole reçu ; ou
pour calculer la valeur absolue de la somme cumulée des différences entre la moyenne imposée P_{ML} de puissance d'onde porteuse et la valeur au carré $r^2(i)$ de chaque symbole reçu.

17. Appareil d'émission par radio selon la revendication 16, comprenant en outre pour chaque niveau de modulation :

un circuit (601) destiné à calculer une valeur au carré de chaque symbole reçu ;
un circuit (602) destiné à soustraire, de la valeur au carré, la valeur moyenne de la puissance d'onde porteuse, qui est imposée pour un niveau de modulation correspondant ;
un circuit (603 à 606) destiné à cumuler un résultat de soustraction par un nombre prédéterminé de symboles ; et
un circuit (607) destiné à calculer une valeur absolue d'un résultat de cumul, et à sortir un résultat de calcul comme valeur de vraisemblance du niveau de modulation correspondant.

18. Appareil d'émission par radio selon la revendication 16, dans lequel :

on fixe une longueur de bloc d'estimation d'un signal émis à un même niveau de modulation en fonction d'un taux d'erreurs d'estimation admis par un système.

19. Appareil d'émission par radio selon la revendication 16, comprenant en outre :

un circuit (702) destiné à obtenir un niveau de signal reçu ; et
un circuit (701) destiné à limiter, en se basant sur le niveau de signal reçu, la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée.

20. Appareil d'émission par radio selon la revendication 16, comprenant en outre :

un circuit (803) destiné à mémoriser un niveau de modulation qui a été estimé le plus récemment ; et
un circuit (801, 802) destiné à limiter, en se basant sur un niveau de modulation qui a été estimé le plus récemment, la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée lorsqu'une estimation actuelle a été faite.

21. Appareil d'émission par radio selon la revendication 16, comprenant en outre :

un circuit (901 à 903) destiné à suspendre une opération ultérieure d'estimation de la valeur de vraisemblance pour un niveau de modulation correspondant si une distance entre des points de signal excède un certain seuil.

22. Appareil d'émission par radio destiné à changer de façon adaptative un niveau de modulation en fonction de l'état d'une voie, comprenant :

un circuit (1201 à 1208) destiné à calculer une valeur de variance d'une puissance d'onde porteuse pour un signal reçu auquel aucune information de niveau de modulation n'est ajoutée lorsqu'il est émis ;
l'appareil comprenant en outre :

un circuit (1209, 1210) destiné à calculer, comme valeur de vraisemblance de chaque niveau de modulation, une différence entre la valeur variance calculée de la puissance d'onde porteuse du signal reçu et une valeur variance de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation ; et un circuit (210) destiné à estimer, comme niveau de modulation du signal reçu, un niveau de modulation correspondant à une valeur de vraisemblance maximale parmi des valeurs de vraisemblance de niveaux respectifs de modulation ;

dans lequel le circuit (1209, 1210) destiné à calculer la valeur de vraisemblance de chaque niveau de modulation est configuré pour calculer la valeur absolue d'une différence entre la variance imposée $\sigma^2_{P_{MI.}}$ de puissance d'onde porteuse et la variance calculée de la puissance d'onde porteuse du signal reçu, c'est-à-dire :

$$\frac{\sum_i^N x^2(i)}{N} - \left(\frac{\sum_i^N x(i)}{N}\right)^2$$

où N est le nombre de symboles reçus, x(i) est la valeur au carré $r^2(i)$ d'un symbole reçu, et i est l'indice de symbole reçu.

23. Appareil d'émission par radio selon la revendication 22, dans lequel :

on fixe une longueur de bloc d'estimation d'un signal émis à un même niveau de modulation en fonction d'un taux d'erreurs d'estimation admis par un système.

24. Appareil d'émission par radio selon la revendication 22, comprenant en outre :

un circuit (702) destiné à obtenir un niveau de signal reçu ; et
un circuit (701) destiné à limiter, en se basant sur le niveau de signal reçu, la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée.

25. Appareil d'émission par radio selon la revendication 22, comprenant en outre :

un circuit (803) destiné à mémoriser un niveau de modulation qui a été estimé le plus récemment ; et
un circuit (801, 802) destiné à limiter, en se basant sur un niveau de modulation qui a été estimé le plus récemment, la plage d'un niveau de modulation pour lequel la valeur de vraisemblance est calculée lorsqu'une estimation actuelle a été faite.

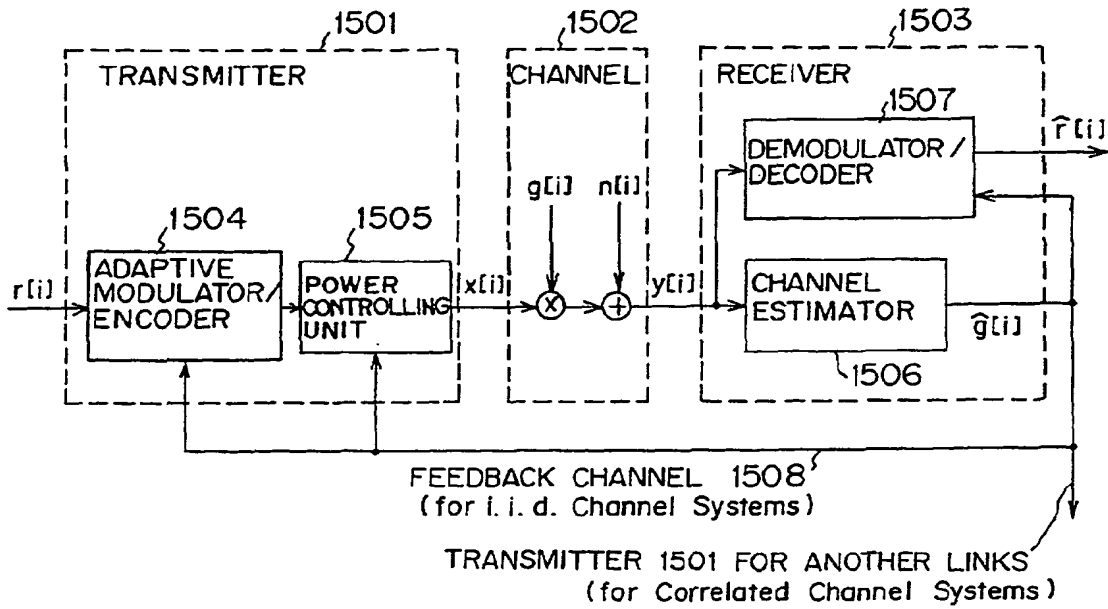**26.** Appareil d'émission par radio selon la revendication 22, comprenant en outre :

un circuit (901 à 903) destiné à suspendre une opération ultérieure d'estimation de la valeur de vraisemblance pour un niveau de modulation correspondant si une distance entre des points de signal excède un certain seuil.

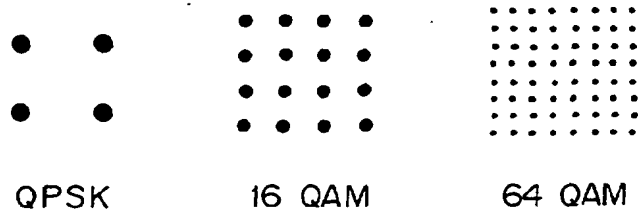**27.** Appareil d'émission par radio selon la revendication 22, dans lequel :

le circuit (1201 à 1208) destiné à calculer une valeur de variance d'une puissance d'onde porteuse pour des signaux reçus est un circuit destiné à calculer une valeur de variance d'échantillons.

28. Appareil d'émission par radio selon la revendication 22, dans lequel :

la valeur de variance de la puissance d'onde porteuse qui est imposée pour chaque niveau de modulation est une variance d'échantillons.

TRANSMITTER 1501

ADAPTIVE MODULATOR/ ENCODER 1504

POWER CONTROLLING UNIT 1505

CHANNEL 1502

$g[i]$ $n[i]$

$x[i]$

$\otimes$ $\oplus$

$y[i]$

RECEIVER 1503

DEMODULATOR/ DECODER 1507

$\hat{r}[i]$

CHANNEL ESTIMATOR 1506

$\hat{g}[i]$

$r[i]$

FEEDBACK CHANNEL 1508
(for i. i. d. Channel Systems)

TRANSMITTER 1501 FOR ANOTHER LINKS
(for Correlated Channel Systems)

SYSTEM MODEL

FIG. 1A

QPSK   16 QAM   64 QAM

EXAMPLES OF SIGNAL POINT ARRANGEMENTS IMPLEMENTED WITH RESPECTIVE MODULATION METHODS

FIG. 1B

104 MAXIMUM LIKELIHOOD
FUNCTION VALUE
SELECTOR

102(#1)

MODULATION LEVEL
ESTIMATING UNIT

Λ
ML#1

RECEIVED
SIGNAL 101

105

MODULATION LEVEL
DEMODULATING UNIT

103(#1)

102(#2)

MODULATION LEVEL
ESTIMATING UNIT

Λ
ML#2

MODULATION LEVEL
DEMODULATING UNIT

103(#2)

DATA SELECTOR

DEMODULATION
SIGNAL 106

102(#X)

MODULATION LEVEL
ESTIMATING UNIT

Λ
ML#X

MODULATION LEVEL
DEMODULATING UNIT

103(#X)

ML: Modulation Level

F I G. 2

RECEIVED SIGNAL
FRAME 201

210 MAXIMUM LIKELIHOOD
FUNCTION VALUE
SELECTOR

202
QPSK
ESTIMATING
UNIT
Λ QPSK

L

QPSK DEMAPPER
206

211
N-DELAY
CIRCUIT

215

203
16QAM
ESTIMATING
UNIT
Λ 16QAM

16QAM DEMAPPER
207

212
N-DELAY
CIRCUIT

204
64QAM
ESTIMATING
UNIT
Λ 64QAM

64QAM DEMAPPER
208

213
N-DELAY
CIRCUIT

DATA SELECTOR

DEMODULATION
SIGNAL 216

205
256QAM
ESTIMATING
UNIT
Λ 256QAM

256QAM DEMAPPER
209

214
N-DELAY
CIRCUIT

F I G. 3

L

ML | I

CONVENTIONAL TECHNIQUE

FIG. 4A

L

I

N

PREFERRED EMBODIMENT

FIG. 4B

ML:Signals for Modulation Level

I:Information Signals

F I G. 5

FIG. 6

EP 0 944 200 B1
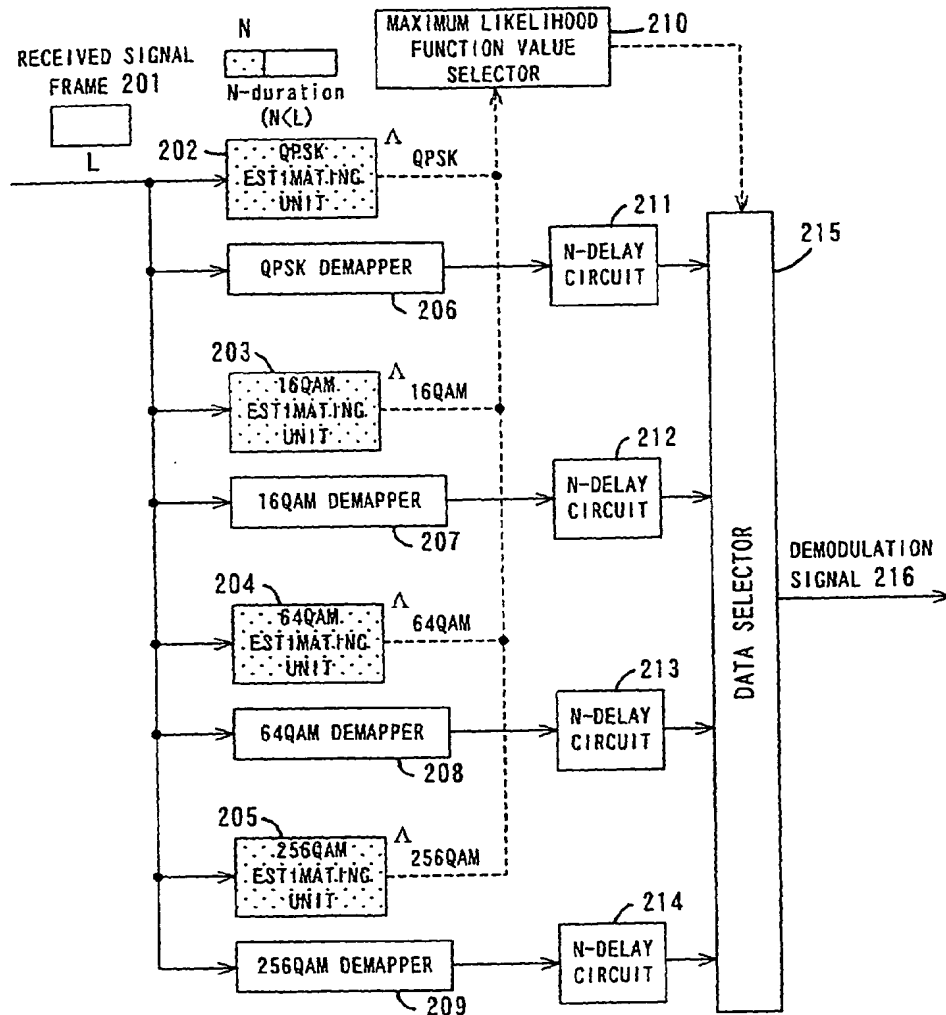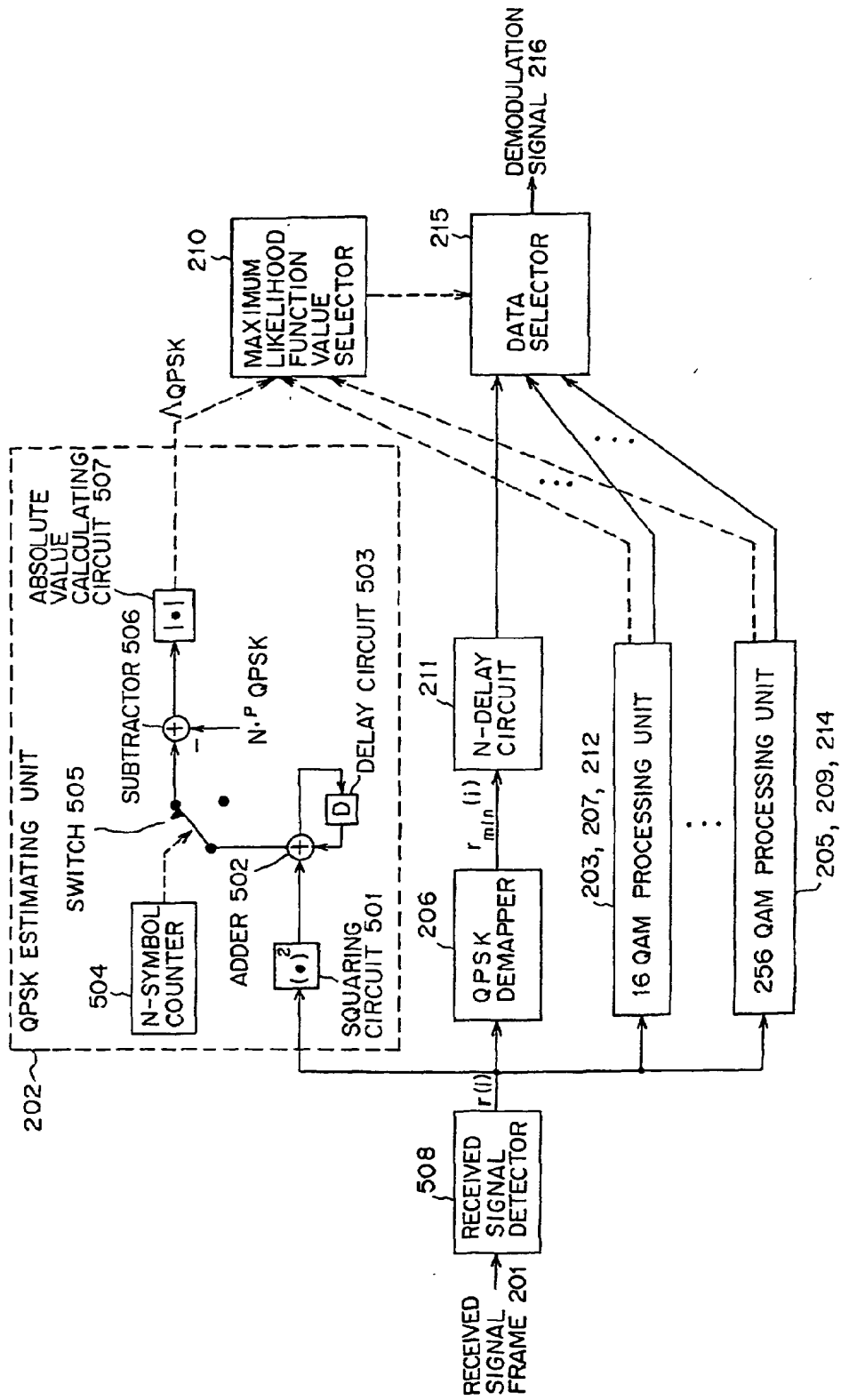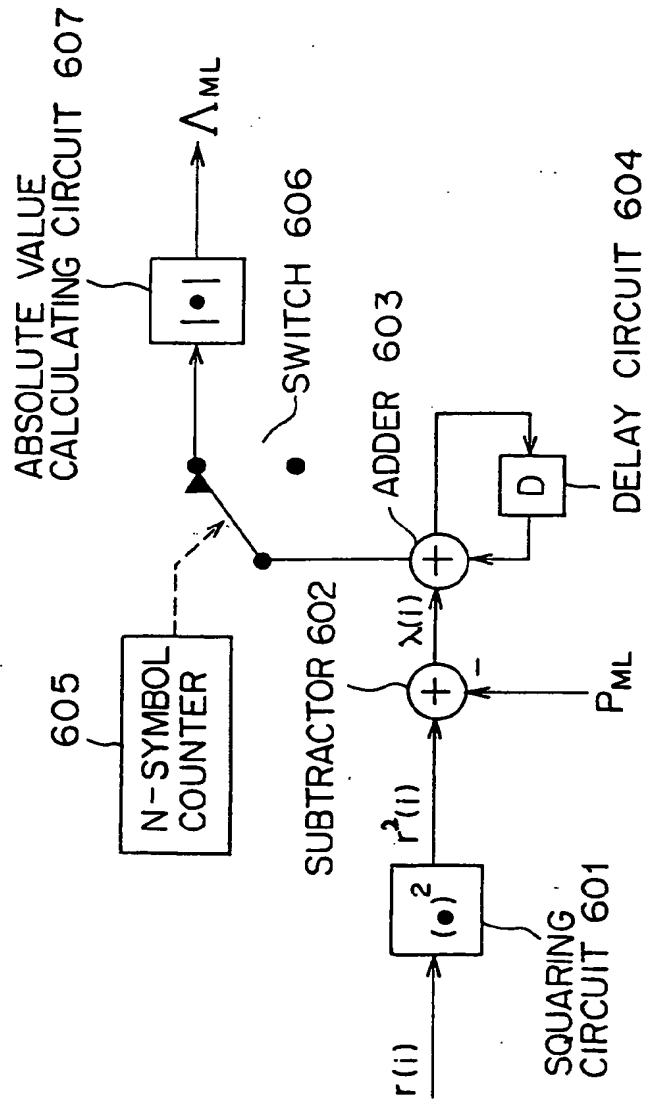
FIG. 7

FIG. 8

F I G. 9

F I G. 10

FIG. 11

NON-ADAPTIVE
MODULATION
SYSTEM
(NAMS)

MS-NAMS
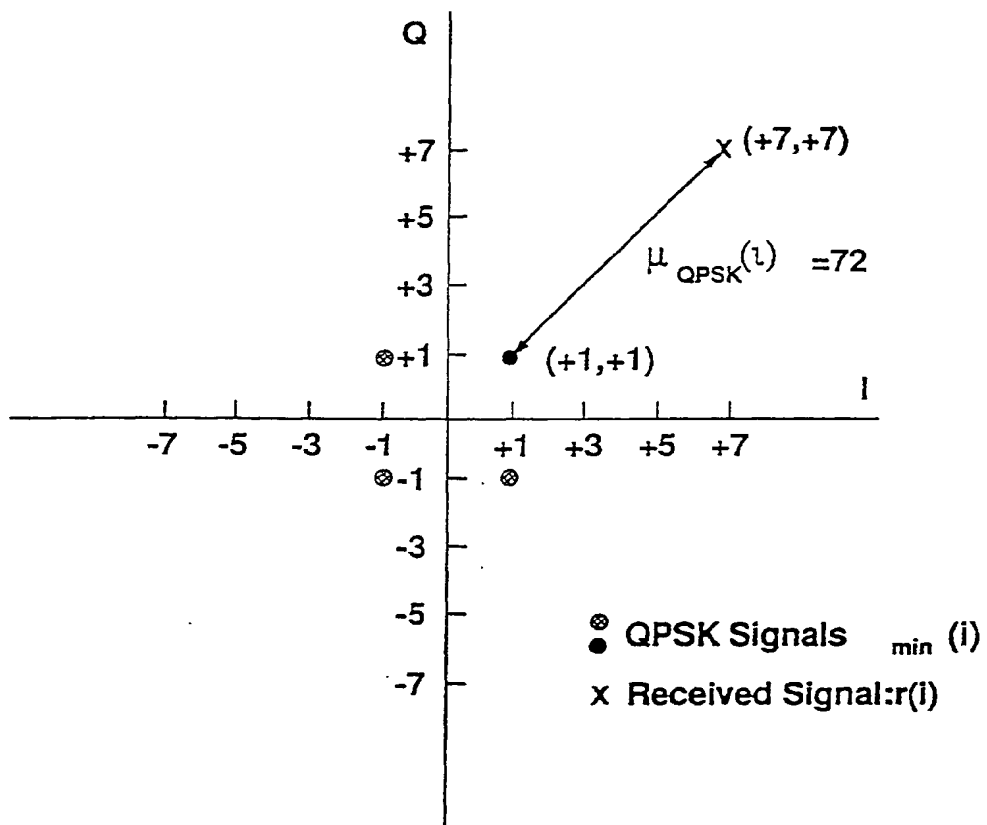
BS-NAMS

MS-AMS

ADAPTIVE
MODULATION
SYSTEM
(AMS)
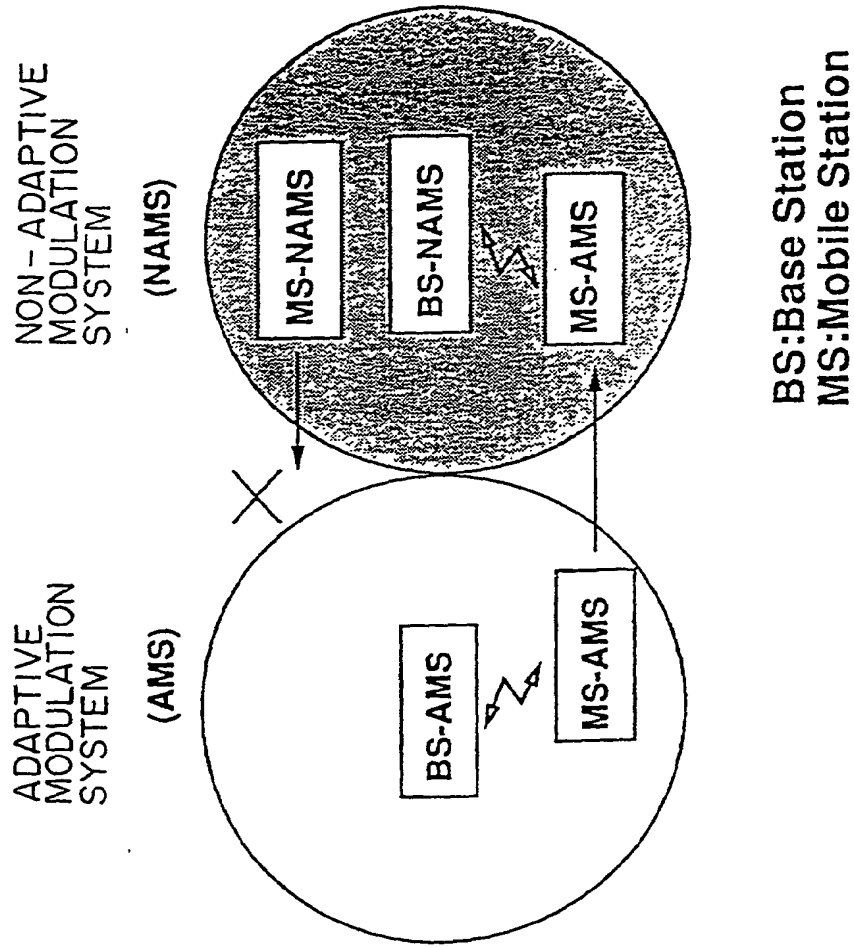
BS-AMS

MS-AMS

BS:Base Station
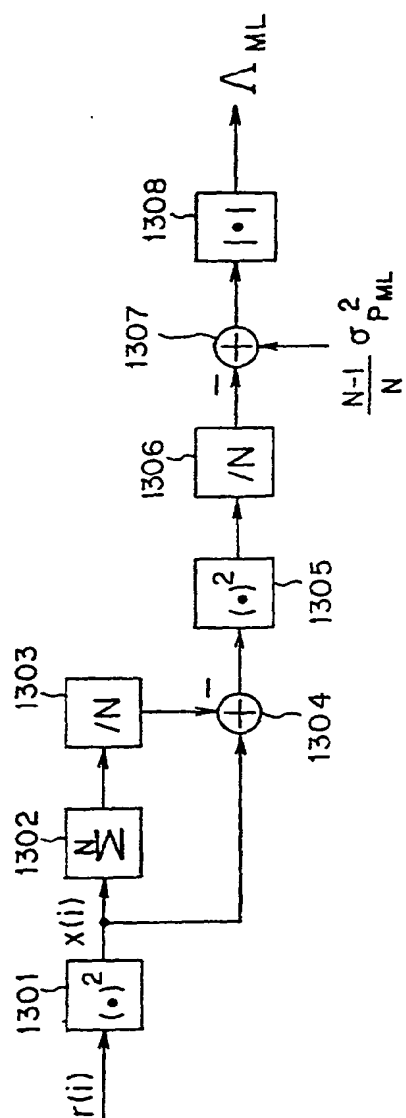MS:Mobile Station
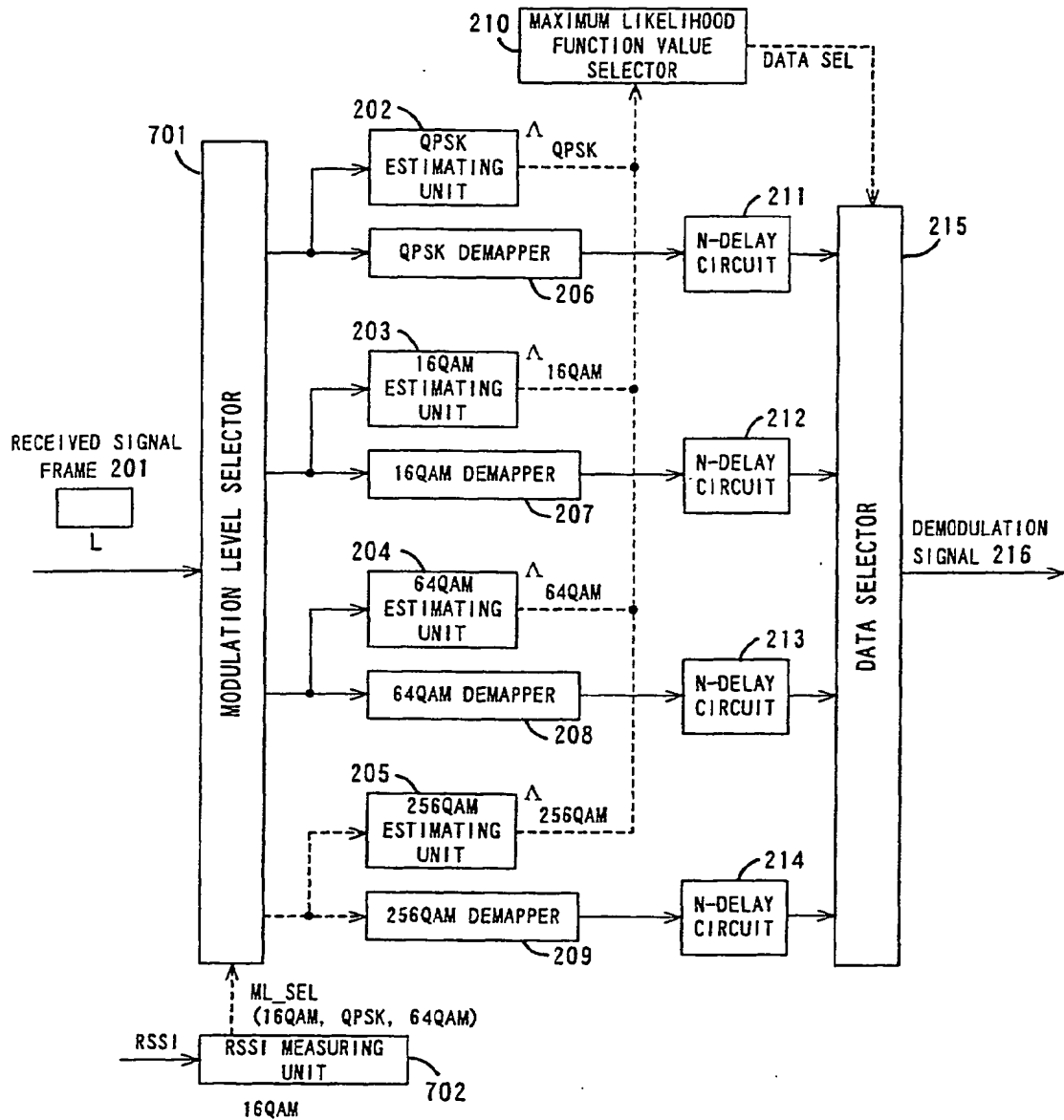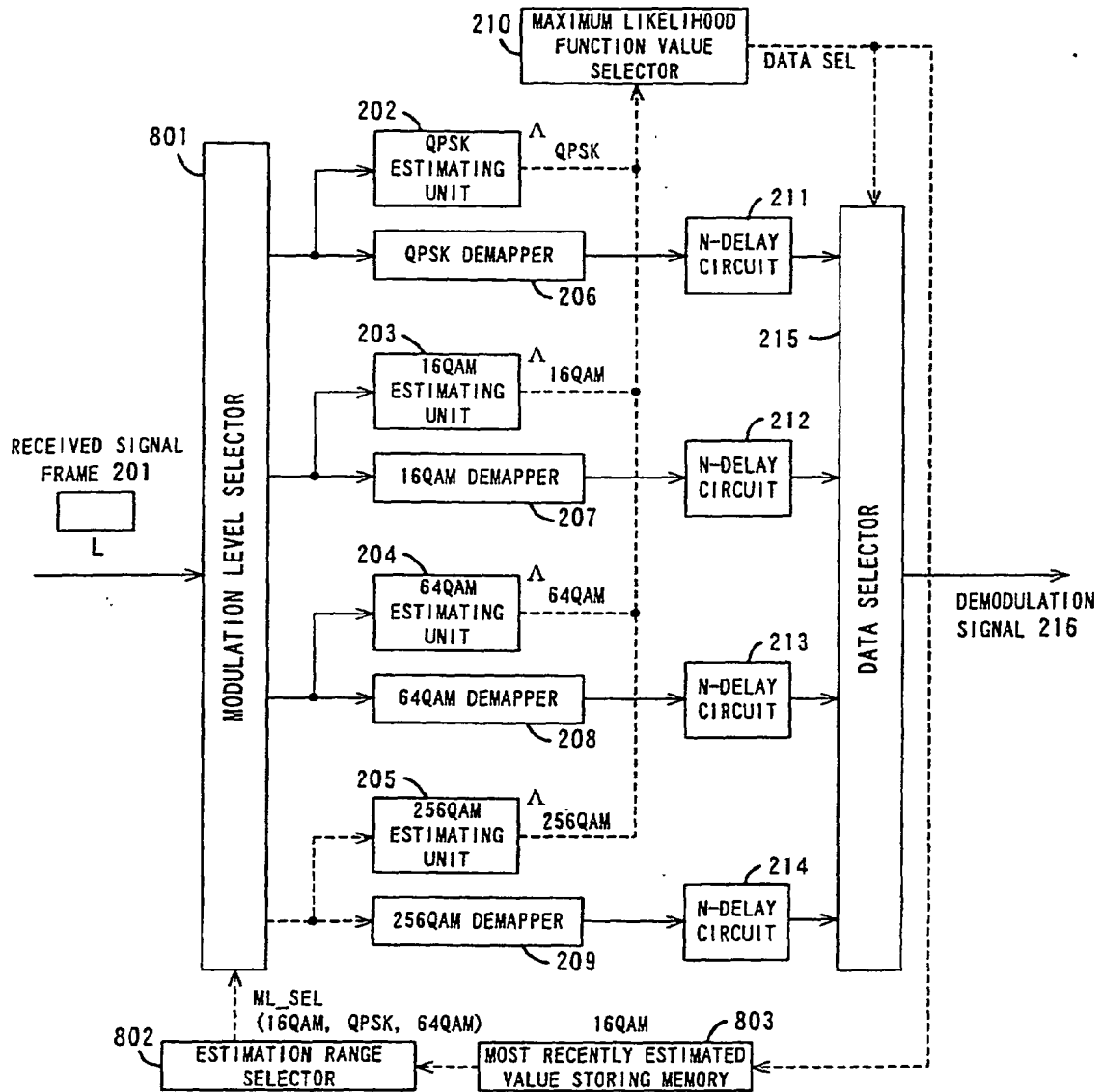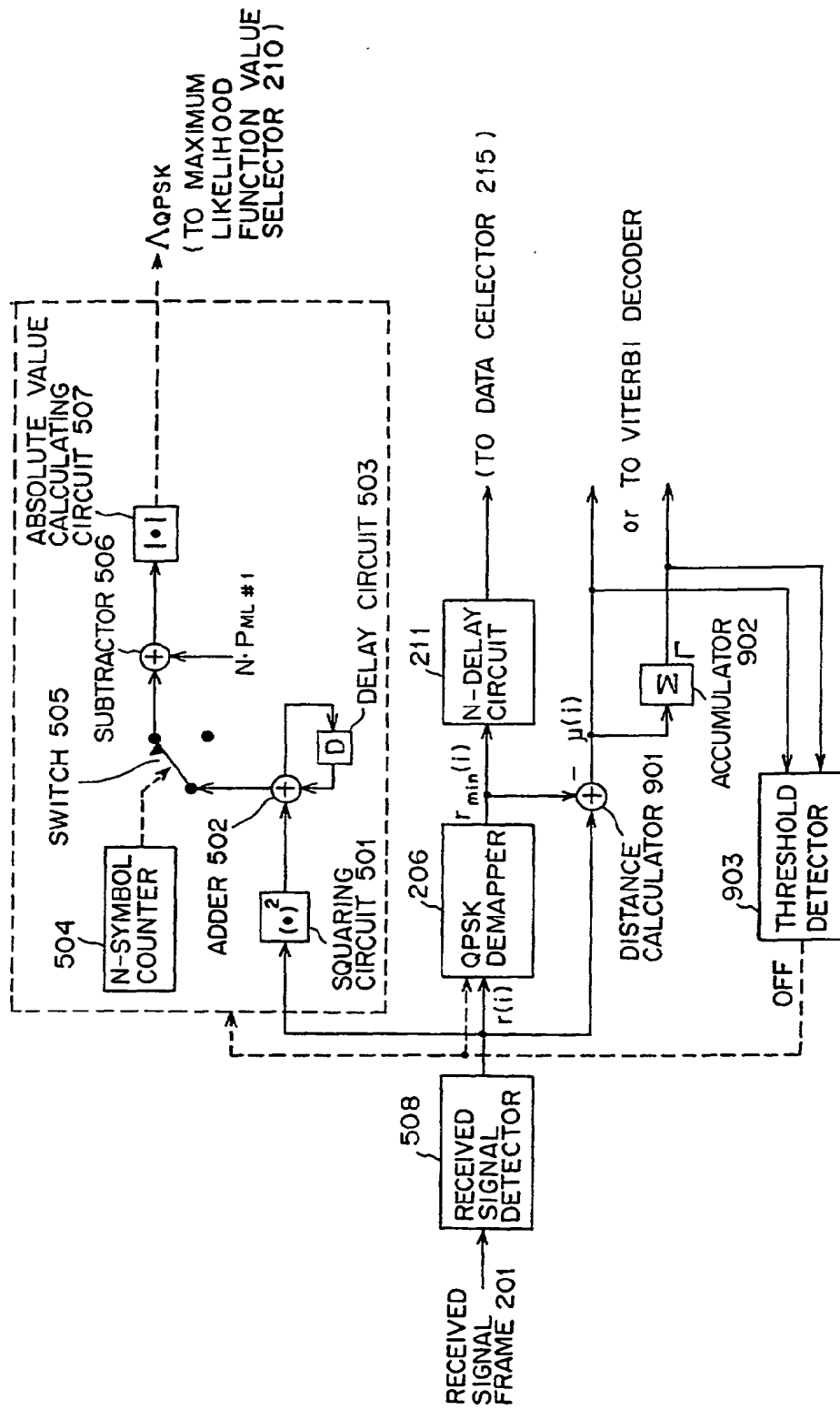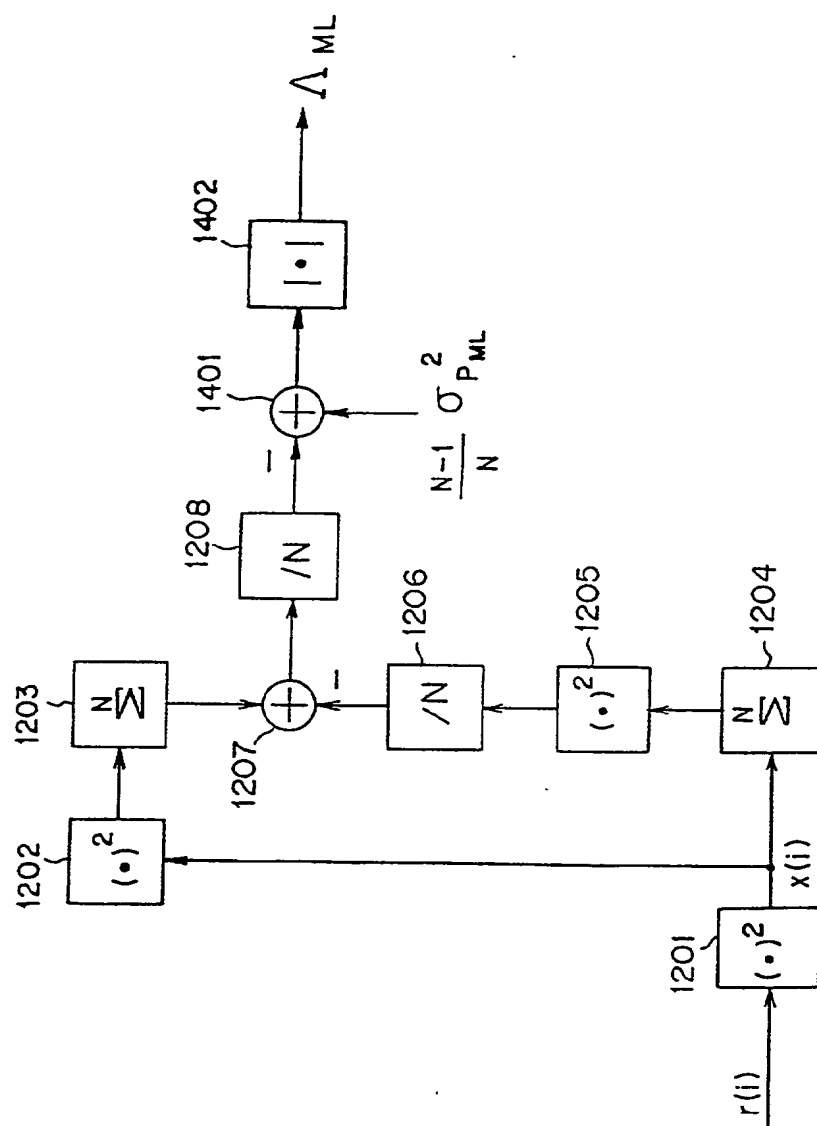
FIG. 12
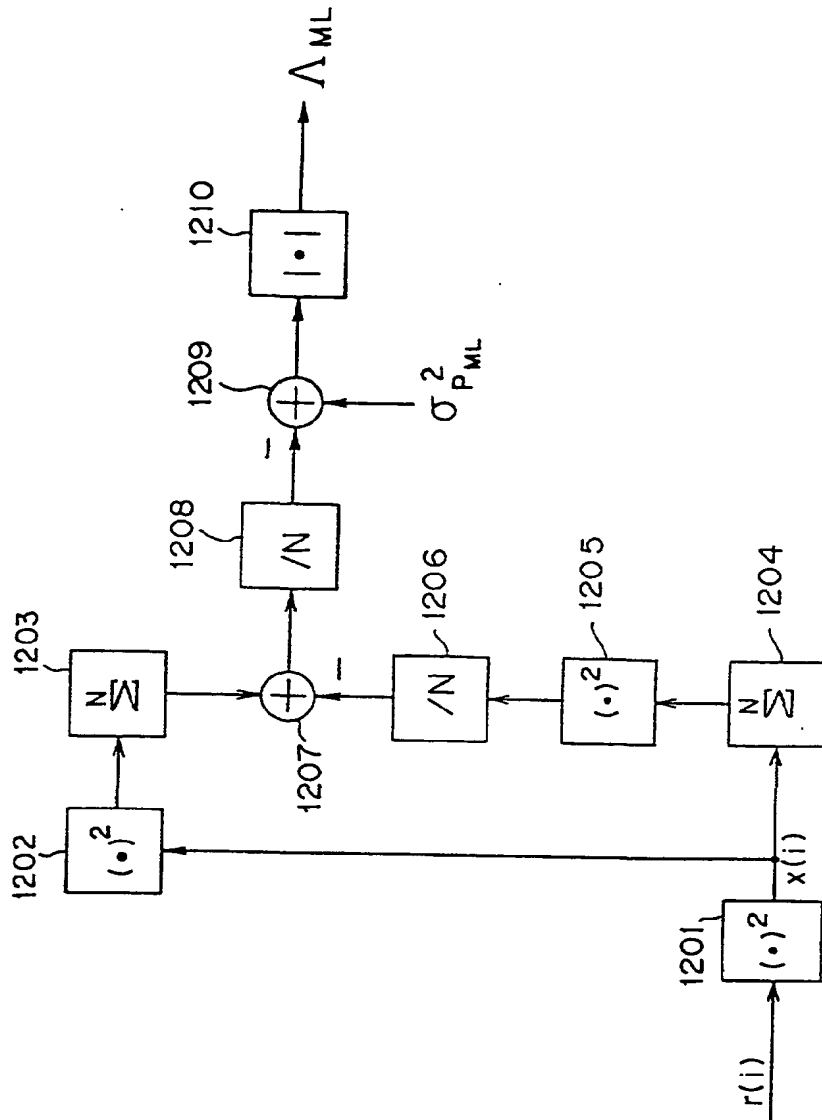
FIG. 13

FIG. 14

FIG. 15

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **Soliman S. Samir et al.** Signal Classification Using Statistical Moments. *IEEE Transaction on Communications,* 1992 **[0025]**